FROM PROMISE TO PURPOSE: OPPORTUNITIES AND CONSTRAINTS FOR ETHANOL-BASED TRANSPORTATION FUELS

By

Kelly Launder

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Abstract

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Ethanol, an alcohol, is most often made from corn but can also be made from other biomass resources. Although ethanol has been in use since the mid-1800s, use and production has varied greatly over the years. Recently there has been a resurgence of interest in ethanol-based transportation fuels. This study focuses on explanations for the revival, and on issues associated with ethanol development. The revival is due, in part, to the need for alternative agricultural markets due to all time low crop prices, mandates requiring fuel additives and alternative fuel vehicles purchases, and recent gasoline price hikes. The strength and persistence of ethanol development is contingent on successfully addressing a number of challenges. Challenges include increasing ethanol use in current markets and expanding its use in new markets; increasing production relative to cost; developing the use of feedstocks other than corn; and optimizing the environmental benefits of ethanol in comparison to the use of petroleum products.

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Chapter 1
Introduction

This thesis focuses on the production and use of ethanol in the United States. Much of the information contained in this thesis was originally published in a report titled "Opportunities and Constraints for Ethanol-Based Transportation Fuels," which I completed in 1999 for the State of Michigan's, Energy Office.[1]

What is Ethanol?

Ethanol is an alcohol made through the fermentation of plant sugars from agricultural crops and biomass resources.[2] The most common agricultural crop utilized for ethanol production is corn (see Figure 1, for process[3]). Only a portion of the feedstock is needed for ethanol production and the remainder can be used for animal feed, corn oil, or other products.

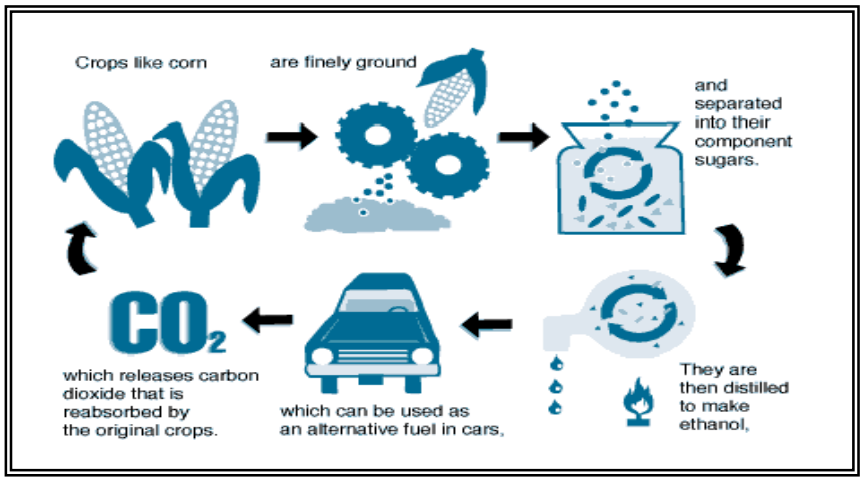

Figure 1: Fuel Ethanol Process

Although the use of ethanol dates back to the mid 1800s, there has been a recent resurgence in its production and use. In 2000, U.S. ethanol production reached an all-time production high of 1.63 billion gallons.[4]

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[1] Kelly Launder, Opportunities and Constraints for Ethanol-Based Transportation Fuels (Lansing: State of Michigan, Department of Consumer & Industry Services, Biomass Energy Program, 1999).

[2] National Ethanol Vehicle Coalition (NEVC), The Future Fuel is Now (Jefferson City: NEVC, 1998).

[3] Renewable Fuels Association (RFA), Less Pollution, Available: http://www.ethanolrfa.org/rfa5.html. 19 January 1999, p.2.

[4] RFA, "Ethanol Industry Surges to All-Time Production Records in 2000," Ethanol Report January 25, 2001, p.1.

Why is There a Renewed Interest in Ethanol Production?

Many factors have contributed to a renewed interest in ethanol-based transportation fuels. One factor is the all-time low price of corn. In 1999, the price of corn dropped to about $2 a bushel, and in 2000 prices dropped even lower. Factoring in inflation, these prices are comparable to those during the Depression.[5] The extremely low price of corn has led to an intense push to create additional markets for corn. One market that many corn-producing states are focusing on is ethanol. Ethanol production creates a large increase in demand for corn and therefore raises the price and increases farmers profits. The U.S. ethanol industry currently uses a total of about 560 million bushels of corn, which boosts the price of corn about 8-10¢ a bushel.[6] The top five corn-producing states in the U.S. now produce ethanol, and many other states (including Michigan) are following suit.

Another factor that has led to a renewed interest in ethanol is fuel additive requirements set by the Clean Air Act (CAA). The CAA mandated that areas with severe ozone pollution use reformulated gasoline (RFG), and that areas with high carbon monoxide pollution use oxygenated fuels (Oxy fuel) during the winter months. The most commonly used additives for oxygenated and reformulated fuels are ethanol and Methyl Tertiary Butyl Ether (MTBE). Ethanol received endorsements as the additive of choice from many environmental groups and legislators when it was recently discovered that MTBE has been leaking into ground water. Due to its infiltration into water systems, MTBE has been banned in twelve states, including Michigan.[7] This has led to the increased use of ethanol as an additive, with the potential for a substantial increase if a nationwide ban of MTBE is passed.

An additional factor that has had an impact on the increased use and awareness of ethanol is the Alternative Fueled Vehicle (AFV) mandate included in the Energy Policy Act (EPAct) of 1992. This mandate requires government and utility/fuel provider fleets to purchase AFVs. Natural gas, propane, methanol, and ethanol all qualify under this Act as alternative fuels. In 2001, 75% of new vehicle purchases by the government and 90% of purchases by utility/fuel providers must be AFVs. The mandates apply to fleets of 20 or more vehicles, in metropolitan areas with a population of 250,000 or more.

In Michigan, 25 counties in the Lower Peninsula are covered by AFV purchase mandates. The mandates could also apply to municipal and private fleets starting in 2002. If the U.S. Department of Energy (DOE) issues a final rule implementing the AFV purchasing requirements for municipal and private fleets, then 20% of new vehicle purchases in 2002 would have to be AFVs. This would increase to, 40% in 2003 and to 70% by 2006. As of February 2001, 392 E-85 vehicles (E-85 is a blend of 85% ethanol and 15% gasoline) were being operated by federal

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[5] State of Michigan, Senate Agricultural Preservation Task Force, Senate Agricultural Preservation Task Force, 1999, p.1.

[6] RFA, Ethanol: Fueling America's Future, Today (Washington: RFA, 1998).

[7] A phase out of MTBE use was approved by the Michigan Congress in June, 2000. A complete phase out by June, 2003 is required.

fleets in Michigan[8]. The State currently operates 667 E-85 vehicles, anticipates purchasing an additional 750 vehicles in 2001 and 2002, and expects to have a total of 4,397 by 2005.[9]

AFV quotas are currently met more often through the purchase of E-85 vehicles then other AFVs because there is no incremental cost for the vehicles. The incremental costs for some AFVs, such as natural gas, can be anywhere from $4,000 to over $10,000.

In addition to the federal, state, and utility fleets, other fleets not mandated to purchase AFVs are operating E-85 vehicles. Michigan State University currently operates about six E-85 vehicles and plans to purchase additional AFVs in the near future. The University of Michigan has approximately 250 E-85 vehicles and plans to purchase an additional 600 AFVs by 2003.[10] Additionally, over 70,000 E-85 vehicles have been purchased by private citizens in Michigan. With more vehicles optimized for E-85 fuel use on Michigan roads, there is an impetus for expanding the E-85 refueling infrastructure. Currently, eight public E-85 refueling sites exist in Michigan. Because there is limited refueling available most ethanol compatible vehicles run exclusively on gasoline (as they can run on either gas or ethanol blended fuel). However, it is projected that as the infrastructure grows and when ethanol production takes place in Michigan, the use of ethanol will expand.

A fourth explanation for the increased interest in ethanol is the recent large gasoline price hikes. In 2000 U.S. gasoline prices soared from all-time lows to all-time highs reaching over $2 per gallon in some areas. Much of the price increase was due to OPEC's decision to decrease oil production to inflate prices. This has brought the issue of our dependence on foreign oil back to the forefront. The U.S. currently imports over 50% of the oil used for transportation fuels and DOE estimates it will increase to 75% by 2010. This dependency on foreign oil can have significant economic and social costs.

The costs of defending foreign oil supplies (such as in the Persian Gulf) are estimated to be $10-$23 billion dollars a year.[11] There are additional costs in maintaining the Strategic Petroleum Reserve, which consists of almost 590 million barrels of oil. At our current consumption rates, if all foreign imports were halted, the reserve would last about 75 days. The cost of maintaining this reserve is high, more then $200 million a year.[12]

One way to decrease our dependency on foreign oil is to increase the domestic supply of transportation fuels. Increasing our use of ethanol can decrease dependency on foreign oil and possibly provide some price relief during gasoline price hikes. A 1996 U.S. General Accounting Office (GAO) report stated that, "Most of the experts we consulted said that in the long term,

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[8] Scott Benson, General Services Administration (GSA), List of Federal E-85 Vehicles, 2001.

[9] State of Michigan, Department of Management and Budget, Alternative Fuel Vehicle Acquisition Activity (Lansing: 1999).

[10] Pat Cunningham, University of Michigan, "Alternative Fuels Usage by University Fleet Vehicles", Michigan Ethanol Workshop Presentation, 2001.

[11] GreenPeace, Fueling Global Warming: Federal Subsidies to Oil in the United States, Available: http://www.greenpeace.org/%7Eclimate/oil/fdsub.html, 1999, p. 2.

[12] United States, Energy Information Administration (EIA), Factsheet: "Biofuels for Energy Security".

sustained research and development on alternative transportation fuels and vehicles may hold the key to significantly reducing the economy's vulnerability to oil shocks."[13] In ethanol producing states like Minnesota, E-85 routinely sells at the same price or less then regular unleaded gasoline. Minnesota has also passed legislation requiring the use of 10% ethanol in all gasoline.[14] Similar legislation has been proposed in Michigan (House Bill No. 4578), but has not yet made it out of committee.

What Are the Implications of Renewed Interest in Ethanol Production & Use?

Although there is renewed interest in ethanol, there are many challenges to overcome before there is widespread ethanol use and production. The main reason for conducting this research is to expand awareness of the challenges associated with increasing ethanol use and production in the United States. Some of the primary challenges are: 1) the need to expand ethanol markets; 2) the need to increase domestic ethanol production and to further develop the production from feedstocks other then corn; and 3) to fully realize (economically and socially) the environmental benefits of ethanol versus gasoline.

Chapter Two of this study will put ethanol in a historical perspective. Chapters Three through Five will address these challenges as well as describe the benefits associated with meeting the challenges.

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[13] The report also stated that, "Most of the experts also believe that the federal government should play a role in funding basic research in this area." United States, General Accounting Office (GAO), Energy Security: Evaluating U.S. Vulnerability to Oil Supply Disruptions and Options for Mitigating Their Effects Publication GAO/GGD 97-41. (Gaithersburg: GAO, 1997) p.64.

[14] Amoco stations have been exempted from this requirement as a settlement from a lawsuit Amoco brought against Minnesota when the mandate was passed.

Chapter 2
Historical Perspective

This chapter will describe the evolution of the use and production of ethanol. This historical overview is important because it will show that contrary to popular belief, ethanol is not a "new" fuel. It has in fact been around as long as petroleum, but has faced significant challenges that petroleum did not have to face.

1850s-1940s

In the late 1850s, ethanol was one of the most popular lamp illuminants; approximately 90 million gallons was produced in the United States.[15] In 1861, two significant happenings affected the use of ethanol as an illuminant. First, kerosene came on the market. Then a $2.08/gallon tax was imposed on alcohol (and therefore, on ethanol) to assist in financing the Civil War.[16] Kerosene quickly replaced ethanol as the premier illuminant due to its cheaper price. In 1906, the alcohol tax was lifted due to complaints by farmers and support offered by Theodore Roosevelt. Lifting the tax renewed interest in ethanol and in 1908, Henry Ford designed the Model T to run on ethanol. By 1914, the production of ethanol had rebounded slightly and reached 10 million gallons. The use of ethanol during World War I perpetuated a further increase in ethanol production to 50 million gallons.[17]

Ethanol use decreased again in 1919 when Prohibition began. Ethanol production was restricted and it could only be sold denatured first, usually with petroleum. Standard Oil Company did attempt to sell denatured ethanol as a gasoline additive (using a 25% ethanol/gasoline blend) in Baltimore starting in 1920. Standard discontinued selling the ethanol blended fuel in 1924, due to high corn prices (which greatly increased ethanol costs) and to problems associated with storing and transporting the ethanol.[18]

Prohibition ended in 1933 and by the early 40s ethanol was again rebounding when it was used during World War II for fuel and to make synthetic rubber. During this period, about 600 million gallons of ethanol was produced annually in the U.S.[19] At the end of World War II, demand for ethanol dwindled and continued to decline for the next two decades, mostly due to cheap petroleum imports. Ethanol wouldn't be used on a large scale again for nearly forty years when it began to be used as a fuel extender.

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[15] David Morris, Ethanol: A 150 Year Struggle Toward a Renewable Future, (Washington: Institute for Local Self-Reliance, 1993) p.1.

[16] Morris, Ethanol: A 150 Year Struggle…, p. 1.

[17] Morris, Ethanol: A 150 Year Struggle…, pp. 1-3.

[18] United States, Department of Energy (DOE), History of Biofuels, Available: http://www.ott.doe.gov/biofuels/ history.html, 29 April 1999, p.1.

[19] Morris, Ethanol: A 150 Year Struggle…, p.3.

1970s

The oil embargo against the U.S. by Arab countries in1973 created petroleum shortages, resulting in significant price increases for gasoline and creating long lines at gasoline stations. The gasoline shortage accelerated concern about U.S. dependency on imported petroleum products, and created an impetus for energy conservation and the development of alternative fuels. The 1978 Energy Tax Act was passed in response to this crisis. This Act exempted ethanol-blended fuel (with at least 10% ethanol) from the 4¢/gallon Federal excise tax imposed on motor fuels. The Act also provided a 10% investment tax credit for ethanol production facilities.[20] Additional incentives were established during the Carter Administration encouraging ethanol production and use. Incentives included offering loan guarantees for ethanol plant construction and funding for ethanol research and development. Nearly 25 federal agencies administered various ethanol programs, and the National Alcohol Fuels Commission was established to study the potential for alcohol based fuels.[21]

1980s

In 1980, three additional ethanol related Act's were passed. The Energy Security Act was created to provide the ethanol industry over $1 billion in loan guarantees. The incentives for increased ethanol production were created to utilize excess supplies of corn caused by the halting of grain exports (including corn) to the Soviet Union. The U.S. had ceased exports in response to the invasion of Afghanistan by the Soviets.[22] The 1980 Crude Oil Windfall Profit Tax Act extended the 4¢/gallon tax exemption for E-10 (gasohol) to December, 1992, and established a blenders credit of 40¢ per gallon, for the blending of ethanol and gasoline. The Omnibus Reconciliation Tax Act instituted a tariff, which priced imported ethanol above the U.S. market price range to protect domestic ethanol producers from cheaper, Brazilian ethanol.[23] Ethanol gained further support in 1980 when Chrysler, Ford, and General Motors released statements that ethanol with blends of up to 10% would be covered in their vehicle warranties.[24] This same year production of ethanol doubled from 20 million gallons to 40 million gallons.[25]

By 1983, most auto companies had approved the use of gasohol in their vehicles. Additionally, this year Michigan became the largest consumer of gasohol in the U.S., consuming approximately 570 million gallons.[26] Michigan's high gasohol consumption was mostly due to a motor fuel tax exemption which, when coupled with federal tax exemptions, totaled 9¢ per gallon and made gasohol cheaper then regular unleaded gasoline.[27]

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[20] United States, GAO, Tax Policy: Effects of the Alcohol Fuels Tax Incentives, Publication GAO/GGD 97-41 (Gaithersburg: GAO, 1997) p.32.

[21] State of Michigan, Department of Agriculture, et al. Alcohol Fuels in Michigan (Lansing, 1983) pp.3-4.

[22] United States, Editorial and Special Issues Department, Government Activity Benefiting Domestic Ethanol Industry (Public Affairs Group: 1996) p.1.

[23] United States, GAO, Tax Policy…, p.33.

[24] RFA, "Ethanol: 20 Years on the Road", Ethanol Report July 2, 1998, p.4.

[25] United States, Editorial and Special Issues Department, Government Activity..., p.1.

[26] State of Michigan, Department of Agriculture, Alcohol Fuels...

[27] The tax exemption was in place from 1980-86.

In 1984, the Tax Reform Act increased the federal tax exemption for E-10 to 6¢ per gallon and the ethanol blenders tax credit to 60¢ per gallon.[28] By 1986, Ford had introduced its first E-85 flexible fuel demonstration vehicle and U.S. production of ethanol had increased to over 700 million gallons[29].

A small setback for ethanol occurred in 1987-88. A drought in the Midwest caused corn prices to rise dramatically and threatened to reduce ethanol producer and blender profit margins. To offset the high corn prices, government corn stocks were sold to ethanol producers at a lower cost and the effects on the ethanol industry were somewhat minimized.[30] The Alternative Motor Fuels Act was passed in 1988 to encourage research, development, and demonstration of alternative fuels and vehicles. According to the National Ethanol Vehicle Coalition, approximately 20,000 E-85 vehicles were manufactured as a result of this act.[31]

1990s

The 1990 Clean Air Act amendments mandated the use of RFG in areas with severe ozone pollution and Oxy fuels during winter months, and in areas with high carbon monoxide pollution. Alcohols, such as ethanol, were designated as the fuels to be used in reformulated and oxygenated gasoline.[32] The Omnibus Budget Reconciliation Act was also passed in 1990. This Act reduced the tax exemption for E-10 to 5.4¢ per gallon, the blenders tax credit from 60¢ to 54¢ per gallon and maintained the 6¢ per gallon tax exemption for E-85. It also extended the tax credit and exemption to the year 2000.[33] Also in 1990, the U.S. Department of Energy encouraged increased ethanol production to replace oil imports after the invasion of Kuwait by Iraq. Ethanol received additional support in 1990 when Chrysler and General Motors recommended the use of ethanol-blended fuels in their new warranty statements.[34]

The 1992 Energy Policy Act mandated the purchase of alternative fueled vehicles in government and private fleets and established a goal of 30% replacement of petroleum fuels by 2010. This Act also expanded the E-10 excise tax exemption to include ethanol blends under 10%. Congress also provided a 12.5¢ tax break for E-85 (fuel tax is 2.5¢ for E-85 vs.15¢ for gasoline).[35] In 1992, General Motors also manufactured approximately 500 E-85 Chevrolet Luminas.[36]

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[28] United States, GAO, Tax Policy..., p.33.

[29] RFA, Ethanol: Clean Air, Clean Water, Clean Fuel (Washington: RFA, 2001) p.2.

[30] United States, Editorial and Special Issues Department, Government Activity..., p.2.

[31] Clean Fuels Development Coalition (CFDC), 1999 Fuel Ethanol Fact Book, p.6.

[32] CFDC, Clean Fuels: Paving the Way for America's Future (Bethesda: CFDC, 1995) p.6.

[33] United States, GAO, Tax Policy…, p.33.

[34] RFA, "Ethanol: 20 Years…" , p.4.

[35] United States, DOE, State Alternative Fuel Laws and Incentives (Washington: Office of Energy Efficiency and Renewable Energy, 1994).

[36] National Ethanol Vehicle Coalition (NEVC), "Why E85 and What's the NEVC?", Ethanol Express, February 9, 2001, p.1.

In 1993, the State of Michigan purchased its first 10 E-85 flexible fuel vehicles and collected data on emissions and operating performance. An E-85 fuel tank was also installed at the State Secondary Complex to refuel the vehicles.

In 1994, EPA proposed a rule mandating that renewable fuels (such as ethanol) be used in 30% of all RFG. However, the American Petroleum Institute and the National Petroleum Refiners Association successfully challenged the rule in court and it was never instituted. Despite this setback, 12% of the gas sold in the U.S. was still blended with ethanol.[37]

By 1995, nearly all car manufacturers recommended the use of ethanol blends up to 10%.[38] Ethanol production was also at an all time high, and more than 1.5 billion gallons of ethanol was produced.[39] A year later, Ford began production of the E-85 compatible Taurus, which became the best selling AFV in the U.S.[40] The first public E-85 refueling station in Michigan was established in Detroit in 1997. Chrysler manufactured E-85 compatible Dodge Caravans, Plymouth Voyagers, and the Chrysler Town and Country minivans.

In 1998, through the Transportation Efficiency Act, the 5.4¢ federal ethanol tax exemption was extended to 2007.[41] This same year, Ford manufactured approximately 90,000 E-85 compatible Ranger pickup trucks and a second public E-85 refueling station was established in Michigan in downtown Lansing.

The National Ethanol Vehicle Coalition recently predicted that, "by the end of 2001 DaimlerChrysler, Ford Motor Company, and General Motors will have produced 1.9 million E-85 vehicles."[42]

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[37] Corn Marketing Program (CMP) of Michigan, Ethanol: Helping to Fuel the American Economy (Lansing: CMP, 1996).
[38] CFDC, Clean Fuels…, pp.44-46.
[39] CMP, Ethanol…
[40] Jerry Roussel, Ford Motor Company, Alternative Fuels Program, Personal communication, March 18, 1999.
[41] RFA, "Congress Votes to Extend Tax Incentive", Ethanol Report May 25, 1998, p.1.
[42] NEVC, "Why E85…", p.1.

Chapter 3
Ethanol Markets

Currently, the largest market for ethanol is transportation fuel for passenger vehicles. Ethanol can be used in passenger vehicles, in any combination of blends, up to 10% without any vehicle modifications. This includes E-10, commonly referred to as "gasohol", oxygenated fuel, and reformulated gasoline (RFG). Higher blends, such as E-85, can only be used in modified vehicles. E-85 flexible fueled vehicles are manufactured by all three major automobile manufacturers, and are modified to run on ethanol blends up to 85%. There are also additional niche markets for ethanol-blended fuels, such as snowmobiles, airplanes, boats, and lawnmowers.

Oxygenated and Reformulated Fuels

Ethanol blends can be used to meet both oxygenated and reformulated gasoline requirements in non-attainment areas for carbon monoxide and ozone. In the first year of the Oxygenated Fuel Program carbon monoxide emission violations were reduced by 90%. It has been reported that through the Reformulated Gasoline Program "air toxic pollution [has been reduced] by over 25%" and "many of the compounds that create ozone pollution, or smog by approximately 17%."[43] To meet oxygenated fuels standards a blend of at least 7.3% ethanol is required. To meet reformulated gasoline requirements a blend of at least 5.4% ethanol is needed.

The Energy Information Administration reported in 2000 that ethanol is the most common additive used for Oxy fuel, and methyl-tertiary-butyl-ether (MTBE) is the most common additive used for RFG. An exception to this is in the Midwest where ethanol is also used more often for RFG.[44]

MTBE

Ethanol is being promoted as a replacement for MTBE in light of water contamination and health concerns. Unlike Ethanol, MTBE is highly soluble in water and travels easily and swiftly to ground and surface water supplies.

Problems with MTBE first surfaced in Alaska where it was blamed for up to 500 complaints of headaches, chronic and severe dry skin, and burning in eyes and lungs. Several hundred residents in New Jersey complained of similar problems. Additional reports of MTBE-related health problems came from Pennsylvania, Montana, Arizona, and other states. Even the American Petroleum Institute (API) has issued warnings on health problems associated with methanol. The Vice President of the API was quoted in the Oil and Gas Journal as saying that

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[43] CFDC, 1999 Fuel Ethanol…, p.16.

[44] United States, EIA, Demand and Price Outlook for Phase 2 Reformulated Gasoline, 2000, Available: http://www.eia.doe.gov/emeu/steo/pub/special/rfg4.html, 18 August 1999, pp. 6-7.

"even small amounts of methanol either ingested or absorbed through the skin can cause blindness, permanent neurological damage, and death."[45]

Maine has opted out of the RFG program due to reported MTBE contamination in water supplies. A study by Maine's Department of Human Services and Environmental Protection found that "detectable levels of MTBE [were found] in…15% of the wells and public water supplies." The study also concluded that more than 1,000 of the water wells in Maine may be "contaminated above [the] health threshold" and that MTBE "mobility and persistence in groundwater is...causing its detection far more frequently than any other constituent of gasoline."[46]

The potential health hazards from use of MTBE is also documented in a recent report from the University of California-Davis titled "*Health & Environmental Assessment of MTBE*" which concluded that "there are significant risks and costs associated with water contamination due to the use of MTBE." Researchers also found MTBE in over 10,000 groundwater sites in California. The report supports the use of ethanol in place of MTBE stating, "the use of...ethanol as an oxygenate...would result in much lower risk to water supplies, lower water treatment costs in the event of a spill, and lower monitoring costs."[47]

The U. S. Geological Survey reported that, "MTBE has been detected in 27% of urban wells nationwide…79% of the wells tested in Denver… [and] 37% of the wells tested in New England."[48] At the end of July, 1999 an EPA advisory panel also concluded that MTBE was a threat to drinking water and recommended that its use be "reduced substantially".[49] In reaction to these findings, MTBE has been banned in twelve states, including Michigan.[50] Federal legislation is pending for a nationwide ban.

If a nationwide ban of MTBE were to be passed and if ethanol were to be used as a replacement for MTBE, ethanol demand would increase to 3.2 billion gallons a year. The petroleum industry argues that these actions would cause significant price increases for reformulated and oxygenated gasoline. However, in an analysis completed by the USDA, it was concluded that ethanol could in fact "replace MTBE by 2004 without price spikes or supply shortages."[51] Some petroleum refiners have begun replacing MTBE with ethanol prior to set deadlines or mandates. Tosco, who is the largest independent petroleum refiner and marketer in

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[45] Fuels for the Future, Methanol Dangers are Cited as U.S. Incidents Increase (Washington: Fuels for the Future, 1994).

[46] RFA, "Maine Requests to opt out of RFG program due to Water Quality Concerns", Ethanol Report, October 15, 1998.

[47] RFA, "UC-Davis Releases Health & Environmental Assessment of MTBE", Ethanol Report, November 12, 1998.

[48] Eric Vaughn, RFA, International Fuel Ethanol Workshop Presentation, June 21, 2000.

[49] CNN, EPA urges less use of smog-fighting gas additive because of cancer risk, Available: http://cnn.com/NATURE/9907/27/PM-CleanGasoline.ap/index.html, 29 August 1999.

[50] California will phase out MTBE use by 2003.

[51] Eric Vaughn, RFA, International Fuel Ethanol Workshop Presentation, June 21, 2000, p.5.

the U.S. announced that it will replace MTBE with ethanol in all of their gasoline terminals in California by the end of 2001.[52]

In June 2001 the Bush administration denied a request from California to be granted a waiver from the oxygenate requirement. California first petitioned President Clinton to be allowed to withdraw from the RFG program and he didn't respond to the request before he left office. The U. S. Environmental Protection Agency denied the request stating, "We cannot grant a waiver for California since there is no clear evidence that a waiver will help California to reduce harmful levels of air pollutants."[53] California will officially phase out MTBE by December 31, 2002. The replacement of MTBE with ethanol will require 580 million gallons of ethanol a year to meet California's oxygenate demand.

Ethanol 10 (E-10/Gasohol)

Alcohol-blended fuels have been used on a large scale since the late 1970s. However, due to the absence of motor fuel standards in the 80s (when alcohol blended fuels were first being widely distributed), there were many incidents of mis-blended gasoline. Consequently, there were consumer complaints about vehicle damage. In 1983 the EPA concluded that, "of 250 samples of unleaded gasoline, [from 150 Detroit stations] 20 had illegal amounts of methanol and 45 had illegal amounts of ethanol."[54] Shortly after this analysis took place, Chrysler sent statements to dealers that mis-blended gasohol and gasoline with methanol could result in corrosion and deterioration of certain vehicle materials and parts; and/or fuel separation, which will cause the engine to stop.
Additionally, 2/3rd of vehicle manufacturers threatened to void warranties if methanol was used in their vehicles. Most manufacturers allowed the use of ethanol blends. Yet, "Honda, Renault, and Toyota said that 10% ethanol blends [could] be used at the owner's risk."[55] As a result of these initial problems, 12 states (including Michigan) adopted alcohol-blended fuel standards and required pump labels identifying gasoline that contained alcohol.

All car manufacturers now approve the use of ethanol blends of 10% or less for all of their vehicles and some even recommend the use of ethanol. For example, General Motors Automobile Warranty, states that, "General Motors recommends use of oxygenated fuels such as... ethanol in gasoline."[56]

With the current high oil prices, the use of E-10 has continued to increase. The Ethanol Producers and Consumers organization recently stated that, "over 12% of gasoline sales in the U.S. are a blend of 10% ethanol..."[57]

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[52] Bryan and Bryan Inc. (BBI), "Tosco Blends Ethanol", The Energy Independent, January, 2001, p.8.
[53] RFA, "Bush Administration denied California Waiver Request", Ethanol Report, June 12, 2001.
[54] State of Michigan, Department of Agriculture, Alcohol Fuels..., p.27.
[55] State of Michigan, Department of Agriculture, Alcohol Fuels..., p.27.
[56] National Corn Growers Association (NCGA), Ethanol: A Clean Breeze Across America, (St. Louis: NCGA, 1990).
[57] Ethanol Producers and Consumers (EPAC), Ethanol Producers and Consumers, (Nashua: EPAC).

E-10 in Michigan

A motor fuel tax exemption was established in Michigan from 1980 to 1984 (and later extended to 1986) for gasohol. The tax exemption decreased over the six year period from 5¢ to 1¢ per gallon. State and federal tax exemptions totaled 9¢ per gallon, which made gasohol cheaper then regular unleaded gasoline. Consumption of gasohol in Michigan increased from 29.3 million gallons in 1980 to 566 million gallons in 1983, making Michigan the highest consumer of gasohol in the United States.[58]

In 1994, the use of E-10 in Michigan sharply decreased. Demand for E-10 in 1997 was less than half of that in 1994.[59] When the labeling laws were proposed, it was argued by four Michigan state government departments (in a report, Alcohol Fuels in Michigan), that "motorists will be confused by the labeling requirements..." and "it is likely that gasohol sales would decline if Michigan adopted a labeling law." The report also refers to studies by Atlantic Richfield, which found that "when consumers are aware that the unleaded [gasoline] is in fact gasohol they tend to shun the product."[60] These labeling requirements may have resulted in lower gasohol sales.

Although, the recent increase in gas prices has precipitated an increase in the use of E-10 in Michigan (over 280 stations in Michigan currently blend ethanol with their gasoline to decrease their costs) a further increase in ethanol use would support instate ethanol production as well as Michigan corn growers. Some possible strategies for increasing the use of E-10 are: 1) Remove the ethanol labeling requirement in Michigan which may discourage consumers from purchasing the fuel; or 2) Require the labeling of
all additives in gasoline and the safety hazards associated with them so fair comparisons to ethanol can be made; or 3) Launch an education campaign to educate consumers on the facts about E-10 to counteract the stereotypes formed in the 80s and to create a positive response when ethanol labeling is used. In the recent study conducted by the Governors' Ethanol Coalition, "Drivers Awareness, Attitudes &Usage Of Ethanol-Blended Fuel", it was found that the two most important messages to convince drivers to use ethanol are: 1) that it reduces emissions and improves air quality and, 2) that it's safe to use and it won't harm their engine.[61]

Ethanol 85 (E-85)

E-85 Vehicles

E-85 compatible vehicles have special hoses, valves, fuel lines, and fuel tanks that resist alcohol corrosion. The vehicles also have a fuel sensor to detect the amount of ethanol in the

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[58] State of Michigan, Department of Agriculture, Alcohol Fuels...

[59] State of Michigan, Department of Consumer and Industry Services, Michigan Energy Appraisal: Semiannual Projections of Energy Supply and Demand Summer Outlook 1998 (Lansing: Public Service Commission, 1998) p.10.

[60] State of Michigan, Department of Agriculture, Alcohol Fuels..., p.23.

[61] Governors' Ethanol Coalition (GEC), Drivers Awareness, Attitudes and Usage of Ethanol Blended Fuel, Cevette and Company, 1997, p.7.

fuel tank, and a larger tank to compensate for the mileage decrease when using ethanol.[62] How much of a mileage decrease occurs when operating a vehicle on E-85 has been recently debated. Ford estimates an average of 16 MPG for E85 Taurus (based on city and highway driving) and 22 MPG for gasoline.[63] DaimlerChrysler reports a 27% range reduction when using E85 in their minivans.[64] Gasoline does contain more energy, gallon for gallon than ethanol. One gallon of gasoline contains approximately 114,132 btu[65] and ethanol contains 76,000 btu. Therefore E-85 contains approximately 27% less btu then 100% gasoline. However, when factoring in the fuel efficiency of gasoline and ethanol (which is more fuel efficient) it was found by researchers that, the "E-85 mileage reduction is only about 10 to 15% instead of the 27% …based strictly on energy content."[66]

General Motors was the first to manufacture E-85 vehicles. In 1992 they produced approximately 500 E-85 Chevrolet Luminas.[67] In 1996, Ford released a flexible fueled Taurus and introduced a Ranger truck in model year 1999. In the first year of production Ford manufactured 100,000 of the E-85 flexible fuel Rangers.[68] In 1998, Chrysler manufactured over 153,000 E-85 vehicles when they introduced three types of flexible fuel minivans-the Plymouth, Grand Voyager, and Chrysler Town and Country.[69] All recently manufactured E-85 vehicles can run on E-85, gasoline, or any combination of both. The automobile Corporate Average Fuel Economy (CAFÉ) standards have been an impetus for automobile manufacturers to produce alternative-fueled vehicles because the industry receives credits for these vehicles.

General Motors has also shown its support of ethanol fueled vehicles by donating Chevy Malibu's to 14 schools for participation in the 1998 National Ethanol Vehicle Challenge and Silverado trucks for the 1999 Challenge. Students re-engineered the vehicles to run on E-85.

One setback is the limited lines and model types of E-85 vehicles being produced by the auto manufacturers. Auto manufacturers have taken strides to correct this. However, currently there is only one passenger vehicle model (the Ford Taurus), four light duty trucks, and three types of DaimlerChrysler minivans on the market. In 2002 General Motors will begin manufacturing E-85 compatible SUV's, and by 2003 a heavy-duty E-85 truck will be made available through Ford.[70]

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[62] United States, DOE, Alternatives…, pp.84-85.

[63] Ford Motor Company, The 1998 E85 Ford Taurus Flexible Fuel Vehicle, 1998.

[64] Chrysler Corporation, Chrysler Corporation's Flexible Fuel Minivans, 1997

[65] btu (BritishThermal Unit) is a standard measurement of heat energy

[66] "a typical automobile utilizes only 12.6% of the energy content input in an urban drive cycle…, and only 20.2% of the energy input during highway operation…meaning that only 20.2% of the energy is actually being used to turn the wheels" NEVC, "E85=How Much Energy Is There", E85 Resource, Winter, 1998, p.3.

[67] NEVC, "Why E85…", p.1.

[68] Ford Company, Alternative Fuel Hotline (1-800-ALT-FUEL), Personal communication, 1998.

[69] Mike Clement, Chrysler Corporation, Personal communication, December, 1998.

[70] State of Michigan, Department of Consumer and Industry Services, Energy Office, Biomass Energy Program, E-85 Informational Card, 2001.

Although the production of E-85 compatible vehicles has greatly increased, the lack of an adequate refueling infrastructure leaves many E-85 vehicles being fueled solely with gasoline. Fuel availability was cited by both federal and state fleet operators as a main consideration in purchasing alternative fueled vehicles.[71]

E-85 Refueling Infrastructure

Fifty to 100 E-85 vehicles are necessary to successfully support an E-85 refueling site.[72] If state and federal E-85 vehicles are targeted to specific areas, those vehicles could support a refueling station until there are enough public E-85 vehicles on the road. To encourage federal fleets to use alternative fuels such as ethanol, President Clinton issued an Executive Order on April 22nd, 2000 directing federal agencies to use "biobased motor vehicle products" when feasible.[73] Additionally, incentives could be used to encourage the refueling of E-85 vehicles with ethanol. For example, Illinois has placed coupons in state E-85 vehicles for drivers to receive a free beverage at E-85 stations. The coupons not only encourage driver's to refuel at E-85 stations, they also make them aware of where the stations are located for future refueling. In June 1999 Ford introduced a similar program to encourage the use of E-85 in their flexible fuel vehicles. Consumers in Chicago, Minneapolis, and St. Paul area who purchase Ford E-85 pickup trucks and live within 15 miles of an E-85 station will be mailed 8 coupons for $5 off the purchase of E-85 fuel and maps with the location of all the current E-85 stations.[74]

The siting of E-85 stations need not be based only on the location of the number of E-85 vehicles in the immediate area. The number of vehicles passing by a particular route should also be taken into consideration and refueling facilities could be established along major transport corridors between metropolitan areas. Federal fleet vehicles in Detroit for example, may travel to Lansing, Grand Rapids or across the state to Chicago, requiring refueling facilities along the I-94 and I-96 corridors.

The penetration of ethanol in the gasoline market has also been hampered due to the inability to transport ethanol via petroleum pipelines. A report to the Chairman of the Committee on Ways and Means (U.S. House of Representatives) states that, "most petroleum pipelines will not carry ethanol because the ethanol can suffer water contamination or cross contamination with other petroleum products, and because of ethanol's corrosive properties."[75] Because of that, ethanol has to be transported by truck or railroad to a blender or to a distributor to be mixed with gasoline. This increases the price of ethanol because pipelines are much cheaper sources of transportation; shipping fuel by pipelines is 25 times cheaper than shipping it by truck.[76]

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[71] Scott Benson, General Services Administration (GSA), Personal Interview, March 2, 1998; William Perry, Michigan Department of Management and Budget, Personal communication, January, 1999.

[72] Peter Porciello, Michigan Department of Transportation, Personal communication, 1998.

[73] RFA, "President Issues Executive Order to Green The Federal Fleet on Earth Day", Ethanol Report, April 27, 2000.

[74] RFA, "Ford Coupon Program to Encourage Use of E85", Ethanol Report, June 3, 1999, p.3.

[75] United States, GAO, Tax Policy…, p.51.

[76] United States, DOE, Alternatives..., p.66.

E-85 in Michigan

Demand for ethanol in Michigan could be increased by expanding the public E-85 refueling infrastructure to accommodate the growing number of E-85 vehicles and by targeting state fleet vehicles to specific areas to support current and new E-85 refueling sites. To determine where additional refueling sites should be sited, a study on vehicle travel could be done with selected fleets or individual owners. The state and federal fleets have a login register for each vehicle, which could be used to pull data on direction and amount of travel. Data on the location of E-85 vehicles in Michigan is available from the Secretary of State.

Currently, Michigan has eight public E-85 refueling sites--three in the Lansing area, two in Battle Creek, one in Rochester Hills, one in Taylor, and one in Detroit. One hindrance to the widespread development of an E-85 infrastructure is the large costs that can be involved in installing new underground tanks for E-85. The Detroit Mobil facility cost the CMP about $52,000, which covered purchase and installation of equipment and application for permits.[77] Although the facility in Lansing only cost approximately $9,000, (for the purchase and installation of the pump), a tank was already in place that could be utilized.[78] With questionable paybacks due to a somewhat unpredictable market, many station owners have been reluctant to take it upon themselves to install E-85 refueling facilities. As the number of E-85 vehicles increase and consequently the potential market for E-85 increases installing E-85 refueling facilities will become more viable. Currently, funding for E-85 refueling sites in Michigan is being led by the Michigan Corn Marketing Program with assistance from the National Ethanol Vehicle Coalition.

To insure that E-85 vehicles are being fueled with ethanol instead of gasoline and that current refueling sites in Michigan are utilized and become profitable, drivers need to be educated about ethanol and where current E-85 sites are located.

Niche Markets

There are also many smaller niche markets where ethanol can be utilized. They are considered niche markets because they are much smaller than the general transportation fuel market. However, they can still create a considerable demand, especially for a much smaller fuel-producing industry like ethanol.

Fuels Cells

One of the newest markets being looked at for ethanol use is fuel cells. Although fuel cells are considered a new technology for vehicles and other applications, they have actually been around for quite awhile. In fact, the basic configuration and idea for fuel cells was discovered in 1839. However, the commercial possibilities of fuel cells weren't realized till the 1960s when NASA began using fuel cells in spacecraft to provide power.[79] In 1998, Chicago

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[77] Keith Muxlow, Corn Marketing Program of Michigan (CMP), Personal interview, April 23, 1998.

[78] Muxlow.

[79] United States, DOE, Los Alamos National Laboratory, Fuel Cells-Green Power, p.2.

became the first city to use pure hydrogen-powered fuel-cell buses.[80] Currently, all big three automobile manufacturers, as well as many foreign auto manufacturers, are developing fuel-cell vehicle prototypes.[81]

Fuel cells work very similarly to batteries except they can run continuously as long as fuel is supplied. Benefits of fuel cells use in the transportation sector include increased energy efficiency, a tremendous decrease in emissions, less vehicle maintenance[82] and the ability to achieve up to 80 mpg. Fuel cells create electricity by combining hydrogen and oxygen. They could eventually be used to supply power to homes, vehicles, and small electronic devices.

Two major obstacles in the development of fuel cells for the transportation sector are storing hydrogen onboard a vehicle (it takes up a lot of room) and developing a hydrogen refueling infrastructure. One way around these obstacles is to create a process to extract hydrogen from already established fuels such as gasoline and ethanol. Benefits of using ethanol versus other fuels include lower emissions and higher efficiency.[83] However, extracting hydrogen from ethanol requires higher temperatures than when using other fuels, such as methanol, and some argue that this may hinder ethanol use in fuel cells. Ethanol may make up for this shortcoming by increasing the amount of energy over methanol (25% higher), which allows for a longer vehicle range.[84] Ethanol is also much less corrosive then methanol.

The use of fuel cells could have a profound impact on our consumption of gasoline. If only 10,000 vehicles were fueled by fuel cells (using a non-petroleum-based fuel, such as ethanol) oil consumption would be decreased by almost 7 million gallons per year.[85] Although fuel cell vehicle prototypes are currently being produced by automobile manufacturers, commercial manufacturing of the vehicles isn't estimated to begin for a few years. Once fuel cells are mass-produced it is thought that fuel cell vehicles may be comparable in cost (over the lifetime of a vehicle) to gasoline vehicles.[86]

E-diesel

Another market for ethanol considered to be in the developmental stage is the use of ethanol blends in diesel fuel. These blends range from 7.7% to 15% ethanol, and 1% to 5%

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[80] These buses are considered for demonstration purposes, showing the potential for fuel cell technology. The buses have very large tanks on the roof to hold the needed hydrogen, which would not be a practical option in general for vehicles. United States, DOE, Los Alamos National Laboratory, p.3.

[81] Toyota and Honda plan to have fuel cell vehicles commercially available in 2003, General Motors and DaimlerChrysler plan to begin production (at least in limited numbers) in 2004. Breakthrough Technologies Institute, Fuel Cells in Passenger Cars…What in the World is Going On? Available: http://www.fuelcells.org/fct/goingon.html, 3 February 2001; DaimlerChrysler, DaimlerChrysler Presents First Driveable Fuel Cell Technology Car in the U.S. Available: http://www.daimlerchrysler.de/news/top/1999/t90317_ehtm, 3 February 2001.

[82] Fuel cells require much less maintenance then an internal combustion engine because like batteries they have no moving parts.

[83] RFA, Ethanol as a Renewable Fuel Source for Fuel Cells, Available: http://www.ethanolRFA.org/fuelcells.htm, 27 September 2000.

[84] United States, Office of Technology Assessment, Renewing Our Energy Future, Publication OTA/ETI/614, 1995, p.133.

[85] Fuel Cells 2000, Benefits of Fuel Cells, Available: http://216.51.18.233/fcbenefi.html, 31 January 2001.

[86] United States, Office of Technology Assessment, pp.136-137.

special additives that prevent the ethanol and diesel from separating at very low temperatures or if water contamination occurs. Ethanol blended diesel could provide a considerable increase in demand for ethanol as diesel vehicles in the U.S. consume approximately 50 billion gallons a year.[87] Demonstrations are currently being conducted on the use of ethanol-blended diesel in heavy-duty trucks, buses, and farm machinery.

The use of ethanol-blended diesel has similar disadvantages to other ethanol-blended fuel, including decrease in gas mileage and increase in cost compared to regular diesel. Advantages include a decrease in emissions and in demand for imported petroleum.

Aviation

A more near-term niche market for ethanol is aviation. Although aviation fuel only accounts for about .5% of the total transportation fuel use in the United States it still represents a sizable market for ethanol consumption (approximately 400 million gallons per year).[88] Currently, ethanol is used in some small engine crafts and by experimental aircraft pilots.

Although the Clean Air Act required the removal of lead in transportation fuels a temporary waiver was given by the EPA for aviation fuels. The EPA is now putting pressure on the aviation sector to take the lead out of their fuel, and it seems likely that Avgas (the leaded aviation standard fuel) will need to be replaced with an unleaded fuel in the near future and that ethanol could be the replacement fuel.

Research on the use of ethanol in aviation began almost 20 years ago. In 1989, the first transatlantic flight on ethanol took place. In March 2000 the FAA certified AGE-85, which consists of 85% ethanol for use in several models of piston-engine aircraft.[89]

The use of ethanol in piston aircraft alone could eventually be a considerable market for ethanol; there are approximately 200,000 piston aircraft in the U.S.[90] However, the road to widespread use of ethanol in aviation may be a long one. Each engine type and airframe/engine together must be certified to run on any "new" fuel, such as ethanol. Receiving certification means that the aircraft can be used for commercial operations when running on the fuel.

As in automobiles, a blend of 85% ethanol fuel can only be used in airplanes that are modified to run on this fuel by installing alcohol compatible components and other minor modifications. In 1997, it was estimated that modifications for a Cessna aircraft would be approximately $3,000.[91] Costs are offset by estimated extended engine life and savings on fuel,

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[87] RFA, "Blends of Ethanol and Diesel Tested in Nebraska Bus Demonstration", Ethanol Report, September 21, 2000.

[88] G. Maben, et al., Department of Aviation Sciences, Baylor University, ETBE As An Aviation Fuel, p.5; BBI, "The Research and Technology Corner", The Energy Independent, April, 2000, pp. 5 & 8.

[89] Two aircraft certified was the Cessna which is the aircraft most used for training, and the Piper the most popular agricultural aircraft in the U.S. Bob Bender, Ethanol: Aviation fuel of the future, 2000.

[90] Dave Higdon, "Treaty calls for Great Lakes ban on leaded fuel", General Aviation News & Flyer, 24 January 1997, p.12.

[91] Caddet, "Ethanol as an Aviation Fuel", Caddet Renewable Energy, Technical Brochure No. 51, 1997.

which could add up to over $6,000 per year.[92] AGE-85 has been shown to have many advantages over the current aviation fuel, Avgas.[93] First, it is much cheaper, selling for about $1.40 per gallon when Avgas was selling at between $2.50-$3.00 per gallon. AGE-85 also provides more power then Avgas because of ethanol's higher octane rating and burns cleaner reducing emissions.

Some constraints in using AGE-85 include its current lack of availability and decreased range (5-15%) due to its lower BTU content.[94] Probably the most formidable constraint to ethanol being excepted in aviation is some opposition within the field itself. The Aircraft Owners and Pilots Association (AOPA) and Cessna have stated that any new unleaded fuel being considered for aircraft should be able to be used without aircraft modifications. They also are doubtful about the ability and willingness of airports to put up a new refueling infrastructure to accommodate a fuel such as AGE-85.[95] Indeed, pilots would most likely have to secure funding or put up the money themselves to install E-85 refueling equipment-at least until widespread use significantly increases demand.

There is also the potential for ethanol to be used in a biodiesel blend and/or ETBE (ethyl-tertiary-butyl-ether) in turbine aircraft, which would not require aircraft modifications. A biodiesel blend would be 20% biodiesel-80% regular diesel and could reduce particulate emissions by 80%. ETBE contains about 43% ethanol and isobutylene a gas/petroleum derivative. This could also prove to be a considerable market for ethanol as turbine aircraft used approximately 16.4 billion gallons of fuel in 1997.[96]

Snowmobiles

Another potential market for the use of ethanol is snowmobiles. Ethanol blends of up to 10% are approved by all major snowmobile manufacturers.[97] Snowmobiles could provide a considerable market for ethanol in Michigan, which has over 278,000 registered snowmobiles.[98] There are a total of over 2.3 million snowmobiles registered in the United States.

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[92] M. Shauck and M. Zanin, Baylor University, Certification of an Aircraft Engine on Ethanol Fuel, p.5.

[93] In a Baylor University, Renewable Aviation Fuels Development Center report it is stated that, "if aviation gasoline and ethanol were both new fuels…there would be no contest between the two fuels. Ethanol would easily prevail. Ethanol outperforms aviation gasoline, is more economical, far better environmentally, and is renewable and domestically produced." M. Shauck and M. Zanin, Renewable Aviation Fuels Development Center, Baylor University, The Future is Now: Ethanol in Aviation, p.10.

[94] Bob Bender, "Ethanol: Aviation Fuel of the Future", Michigan Ethanol Workshop Presentation, 2000.

[95] "The Future of Avgas…", The Fuel Market, April 1996, p.65.

[96] Shauck, The Future is Now…, p.4.

[97] ArcticCat, Polaris, SkiDoo/Bombardier, and Yamaha all approve up to10% ethanol blends in their snowmobiles. However ArcticCat and Polaris recommend snowmobile modifications before using. ArcticCat also stipulates that "when using ethanol blended gasoline, it is not necessary to add a gasoline antifreeze since ethanol will prevent the accumulation of moisture in the fuel system". Iowa Corn Promotion Board, Small Engine Manufacturers Recommendations on Ethanol Use, Available: http://www.iowacorn.org/semr.htm, 22 January 2001.

[98] State of Michigan, Department of State, Recreational Vehicle Registrations, Available: http://www.sos.state.mi.us/vehiclereg/00recvehicleregs.pdf, 30 September 2000.

One reason to consider the use of ethanol in snowmobiles is that it greatly decreases emissions. This is a significant factor to consider as a snowmobile with a conventional 2-stroke engine emits 36 times more carbon monoxide and 98 times more hydrocarbons than an automobile. In fact, snowmobiles can pose such serious environmental and health risks that many national parks are considering limiting or banning the use of snowmobiles within the parks. Using a blend of 10% ethanol also eliminates the need for the use of gas-line antifreeze (as it absorbs excess moisture) and removes and prevents deposit buildups in the fuel tank.[99]

Boats/Marine

Ethanol blends of up to 10% can also be used in boats and personal watercraft. This could also prove to be a considerable size market in Michigan. In September 2000, Michigan had almost 830,000 registered boats/watercraft.[100] Many marine/boat manufacturers approve the use of ethanol-blended fuels.[101] However, some boat manufacturers do have cautionary language on the use of alcohol based fuels in older boats as they may not have alcohol compatible parts and therefore certain parts could be degraded with the use of ethanol blended fuels.[102]

Small Engine Equipment

Ethanol-blended fuel can also be used in small engines such as lawnmowers, chainsaws, and weed trimmers. The Portable Power Equipment Manufacturers Association has conducted reformulated fuel research for chainsaws, weed trimmers and other hand held equipment and found "no operating problems with equipment when using reformulated gasoline."[103] The benefits of using ethanol would again be decreased emissions. It has been reported by the California Environmental Protection Agency that, a "gasoline-powered lawnmower run for an hour puts out about the same amount of smog-forming emissions as 40 new automobiles run for an hour."[104] They also reported that a chain saw operated for 2 hours can generate the same amount of emissions as ten automobiles driven 250 miles."[105]

Niche Market Summary

Although the use of ethanol could result in emission decreases in many niche markets, there has been concern raised by consumers and some manufacturers about the use of ethanol in small engines such as in snowmobiles, watercraft, and hand-held equipment. One concern is due to the seasonal nature of machine use and the longer storage periods necessary for these products. Many manufacturers therefore recommend draining fuel from the equipment or adding

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[99] State of Minnesota, Department of Agriculture, Breathe Easy: Snowmobiles Run Great On Ethanol.

[100] State of Michigan, Department of State.

[101] Honda, Kawasaki, Mercury, OMC, Pleasurecraft, Tigershark, Tracker, and Yamaha all approve up to10% ethanol blends in their products. Iowa Corn Promotion Board.

[102] Mercury Marine states that degradation problems may occur with boats older then 1979;OMC for boats older then 1985. Iowa Corn Promotion Board.

[103] RFA, Get the Facts About Ethanol Enhanced Fuel in Small Engines, (Washington: RFA).

[104] California Environmental Protection Agency, News Release: "Mow Down Pollution with Electric Mower Rebate", May 20, 1999, Available: http://www.arb.ca.gov/newsrel/nr052099.htm, 1 April 2001.

[105] California Environmental Protection Agency, Fact Sheet: "Reducing pollution from small engines", Available: http://www.arb.ca.gov, 1 April 2001.

a stabilizer.[106] Some have also raised concerns about a decrease in lubricity when using ethanol-blended fuel. Vavoline Oil conducted research on the lubricity of ethanol fuel in small engines and found that they "may actually provide better lubricity than regular gasoline."[107] Another concern is phase separation. Because ethanol is an alcohol, it will absorb excess moisture. If enough is absorbed, the ethanol will separate from the gasoline and cause operation and/or corrosion problems. It would, however, take a relatively large quantity of water for this separation to occur.[108]

An Iowa Corn Promotion Board publication on small engine manufacturers recommendations on ethanol use reports that, even if some manufacturers discourage the use of ethanol-blended fuel, that may be an indication of the manufacturers lack of research and testing on the use of these fuels in their products rather than an indication that these fuels are unsafe to use. They also state that consumers should make sure that any new products they purchase are compatible with oxygenated fuels as "it is anticipated that 50% of all gasoline sold in the U.S. will contain oxygenates."[109]

Ethanol Markets Summary

Because ETBE, E-10, and any blend of ethanol under 10% can be used without vehicle modification and distributed through the existing infrastructure, increasing the use of these blends can be done more expediently and with little or no incremental expense. This may be accomplished through policy initiatives, public education and promotion.

If state and federal government agencies continue to increase the amount of E-85 vehicle acquisitions and target vehicle assignments to specific areas, a sufficient demand will be created to establish additional public refueling sites. Then, the focus can shift to establishing public E-85 refueling stations along major corridors to service both fleet vehicles as well and private citizens. As demand for all these blends of ethanol increases, it will support both new and existing ethanol production facilities.

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[106] Iowa Corn Promotion Board.

[107] RFA, Get the Facts …

[108] It would take about 12 teaspoons of water per gallon in the gas tank for separation to occur. For phase separation to occur due to water absorption it would take over 300 days at 100% humidity with the gas tank cap off. (Iowa Corn Promotion Board) Also, a gallon of gasoline can only hold .02% water whereas ethanol can hold .5%. (RFA, Get the Facts …)

[109] Iowa Corn Promotion Board.

Chapter 4
Ethanol Production

Overview

The production of ethanol rose steadily in the 1980s, peaking in 1995. However, high corn prices at the end of 1995 and into 1996 significantly increased ethanol production costs. At the same time, oil prices fell. Consequently, ethanol demand and production dropped. Since 1996, production has been steadily increasing again, with a large increase occurring in mid-1997.[110] In 1998, total production was over 1.36 billion gallons,[111] and production reached an all-time high of 1.63 billion gallons in 2000.[112]

Even with these current increases in ethanol production, the industry has had to overcome many challenges, and the industry continues to face a variety of issues. One issue is whether ethanol has a negative energy balance (i.e., takes more energy to produce than the energy output when it is utilized). With earlier ethanol production, energy balance was a concern due to poor design and lower yields. In a report by Dale Monceaux of KATZEN International, the author notes that many early ethanol plants were designed after distillery plants. This led to inefficiencies in fuel ethanol production. Instead of focusing on optimizing yield and energy efficiency (which is important in fuel ethanol production), distillery plants focused on "consistency in flavor and quality of product." Monceaux contends that, because these plants were "labor and energy intensive and operated with poor yields, the drop in ethanol price during the mid-80's resulted in most of the beverage-distillery-technology-based …producers [to cease] operations."[113]

Reports on the negative net energy balance for ethanol resurfaced in the late 1980s and early 1990s when ethanol production was again on the rise. However, a 1995 USDA Economic Research Service Report concluded that there is a positive net energy balance and, in fact, that "for every BTU dedicated to producing ethanol, there is a 24% energy gain."[114] This is attributed to technological improvements, as well as to increased efficiencies in crop production and yields. This report also disputes the findings of previous studies, which concluded that there was a negative energy balance for ethanol. The use of old data, which didn't account for more recent energy efficiencies, technological improvements, and other variables, is blamed for the incorrect energy balance conclusions.[115]

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[110] Hart Publications Inc., "Ethanol, MTBE Production Volumes Strong in 1997", Oxy-Fuel News, Feb. 9, 1998, p.8.

[111] RFA, Press Release: "U.S. Ethanol Production Tops All Time High", December 1, 1998, Available: http://www.ethanolrfa.org/pr120198.html. 19 January 1999.

[112] RFA, "Ethanol Industry Surges…", p.1.

[113] Dale Monceaux, KATZEN International Inc., 2000 International Fuel Ethanol Workshop & Trade Show Presentation: "Achieving High Ethanol Yield", p.2.

[114] United States, Department of Agriculture (USDA), Estimating the Net Energy Balance of Corn Ethanol, Agricultural Economic Report No. 721 (Washington: Economic Research Service, 1995) p.14.

[115] USDA, p.4.

A second challenge the ethanol industry may soon face is significantly increasing production in a very limited time period. If MTBE use is banned across the country, as federal legislation introduced in February of 2001 calls for, ethanol production would have to increase quickly to replace MTBE demand. To completely replace U.S. MTBE demand, ethanol production would have to increase to almost 3.2 billion.[116] This would, in turn, increase the use of corn from 500 million bushels annually to 1,100 million bushels annually. Considering that in 1999 farmers in the U.S. exported approximately 1,929 million bushels of corn, it is likely that farmers would be able to meet this increased domestic demand for corn.

The challenge would be to construct new ethanol plants and increase the production capacity of current plants to meet the increase in demand. A recent report by the Governor's Ethanol Coalition on the ability of the ethanol industry to expand and meet this increase in demand, stated that the ethanol industry should have no problem meeting this demand considering that the "U.S. ethanol industry can virtually double capacity within a two-year timeframe."[117] This increased production will come from "increased capacity utilization, the expansion of current facilities, and the construction of new facilities." The report also states that current ethanol production facilities are only operating at 82% of their capacity. Increasing production to 90% of capacity, could produce an additional 180 million gallons of ethanol. Current plants can also be expanded to increase ethanol production. Researchers found that, not only could current facilities be expanded more quickly then new facilities could be constructed, but that expansion would also be much cheaper (about half the cost).[118] Through the expansion of current facilities, another 1.2 billion gallons of ethanol could be produced within a relatively short period of time.[119] The report also found that, within the next year, ethanol production facilities currently under construction will provide an additional 134 million gallons of ethanol a year.[120] Ethanol production facilities that are in various stages of planning would add another 1 billion gallons of production. It was additionally reported that, if this expansion of the ethanol industry occurs, farmers' profits will increase by $2.3 billion and create 65,600 jobs.[121]

A third ethanol production challenge is to expand the production of ethanol through alternative feedstocks (other then corn). With biomass ethanol production, there are an abundance of inexpensive feedstocks available. When low-valued agricultural by-products and wastes (such as food processing by-products and municipal solid waste) are used, a waste disposal solution is available in addition to producing a valuable product. Biomass ethanol production is expected to continue to increase as technology in that area develops and improves. In fact, 12 out of 32 ethanol plants currently being planned are biomass ethanol facilities.[122]

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[116] John Urbanchuk, AUS Consultants, Ability of the U.S. Ethanol Industry to Replace MTBE, Report Prepared for the Governors' Ethanol Coalition, March 20, 2000, Available: http://www.ethanol-gec.org/ability.html 7 March 2001, p.1.

[117] John Urbanchuk, p.1.

[118] It takes about 10-12 months to expand production at an existing plant and about 15-20 months to build a dry mill ethanol plant. John Urbanchuk, p.7.

[119] John Urbanchuk, p.7.

[120] John Urbanchuk, p.7.

[121] Approximately 47,800 in the ethanol industry and 17,800 in other areas. John Urbanchuk, pp.12-13.

[122] John Urbanchuk, pp. 8-9.

Production and employment

Increasing ethanol production creates jobs. USDA estimates that "a 100 million gallon ethanol plant could create 2,250 local jobs for a community."[123] More than 195,000 jobs have already been created due to the ethanol industry.[124] In addition to the number of jobs created, many of these jobs are created in rural, economically depressed areas.

Economic Activity and Incentives

Ethanol production also adds value to agricultural crops and helps retain profits locally. The Corn Marketing Program estimates that "nearly 80% of the money generated by an ethanol plant is spent within a 50 mile radius of the factory."[125] Due to the rise in ethanol demand and production in 1997, there was an increase of more than $3.6 billion in Federal tax revenues and over $450 million in additional state tax receipts (for all states combined). There were also $11.6 million in additional Michigan tax receipts from ethanol-related economic activity. This increase in economic activity may justify the 54¢ federal tax incentive, which cost $0.6 billion in 1997.[126] The Renewable Fuels Association contends that new technological developments and the extension of the tax incentive to 2007, is responsible for the current increase in ethanol production and facilities.[127]

State tax incentives have also played an important role in stimulating ethanol production. A 1997 report to the U.S. House of Representatives by the General Accounting Office states that "the economic viability of the ethanol industry depends on the size of state subsidies as well as the federal incentives" and that the "state tax incentives combined with the federal exemption of 54¢ per gallon, allow ethanol to compete profitably with substitute fuels."[128] State production and blender credits range from 20¢ to 40¢ per gallon of ethanol, and tax exemptions range from 10¢ to 80¢ per gallon.[129]

Factors for in-state production

Table 1 (pages 24-25) lists ethanol production, ethanol incentives, non-attainment status for Carbon Monoxide (CO) and Ozone, corn production ranking, and ethanol use for selected states. It can be inferred from this table that state-based ethanol incentives, corn production, air quality status, and ethanol consumption may all contribute to in-state ethanol production.

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[123] RFA, Ethanol: Fueling America's...

[124] NEVC, E85: Fueling the Future Today (Jefferson City: NEVC, 1998).

[125] CMP, Ethanol…

[126] Michael K. Evans, The Economic Impact of the Demand for Ethanol (Lombard: Midwestern Governor's Conference, 1997), p.1.

[127] RFA, Press Release.

[128] United States, GAO, Tax Policy…, p.51.

[129] United States, GAO, Tax Policy…, p.51.

Table 1: Incentives, Air Quality Status, Corn & Ethanol Production, and Use of Ethanol by State

State	Ethanol Fuel Incentives[130]	CO non-attainment/ Oxy fuel prog.[131]	Ozone non-attainment/ RFG prog.[132]	1999 Corn Production Ranking[133]	*Plants/ Capacity (MGY)[134]	**1999 Ethanol Use (gallons)[135]
California		Yes /	Yes / Yes- SA	23rd	2 / 6.7	52,384,000
Colorado		Yes / Yes-SA		13th	1 / 1.5	47,925,000
Connecticut	Tax exemption	Yes / Opt-in	Yes / Opt-in	NA	0 / 0	3,280,000
Florida			Opt-in /	37th	1 / 5	897,000
Idaho	Tax exemption			33rd	2 / 7.0	NA
Illinois	Tax exemption		Yes / Yes-SA	2nd	5 / 672	215,565,000
Indiana		Yes /	Yes / Yes-SA	5th	1 / 88	95,281,000
Iowa	Tax exemption			1st	6 / 358.5	70,900,000
Kansas	Producer credit		Opt-in /	6th	4 / 38.1	5,252,000
Kentucky	Tax exemption		Yes / Yes-SA	14th	1 / 12	3,298,000
Louisiana			Opt-in /	21st	1 / 20	1,476,000
Michigan		Yes /	Opt-in /	10th	0 / 0	35,898,000
Minnesota	Tax exemption Producer credit	Yes / Yes	Yes /	4th	15 /230.5	206,542,000
Missouri	Producer credit		Opt-in /	11th	2 / 40	15,257,000
Montana	Producer credit	Yes / Yes-SA		40th	0 / 0	411,000
Nebraska	Producer credit			3rd	8/ 303	22,127,000
N. Dakota	Producer credit			15th	2 / 38.5	4,630,000
New Mexico		Yes /		30th	1 / 12	21,030,000
Ohio	Blender credit	Yes /	Opt-in /	8th	0 / 0	207,956,000
S. Dakota	Tax exemption Producer credit			9th	4 / 69	19,124,000

Table continued on next page

*Includes plant still under construction
**Does not include E-85 use
Opt-in State participation is voluntary
MGY Million Gallons per Year
NA information not available
SA Selected areas in the state

Note: Areas participating in the Oxygenated (Oxy) fuel program sell oxygenated gasoline during winter months
Areas participating in the Reformulated Gasoline (RFG) Program sell RFG year-round

130 United States, DOE, State Alternative Fuel Laws…; United States, DOE, 1997-98 Tax Guide for Alternative Fuels, 1998, Available: http://www.afdc.doe.gov/taxes/1998/fed-tax.html 27 January 1999.

131 HART/IRI Fuels Information Services & ARCO Chemical, 1994 United States Fuel Reformulation Map (Potomac: HART,1994).

132 HART/IRI Fuels, 1994 United States…

133 NCGA, The World of Corn 2000 (St. Louis: NCGA, 2000) p.8.

134 NCGA, The World of Corn 1998 (St. Louis: NCGA, 1998); BBI, U.S. Ethanol Production Capacity, 2000.

135 United States, Department of Transportation, Federal Highway Administration, Estimated Use of Gasohol-1999, Available: http://www.fhwa.dot.gov/ohim/hs99/tables/mf33e.pdf

Tennessee		Yes /	Opt-in /	18th	1 / 45	NA
Texas		Yes / Yes-SA	Yes / Yes-SA	12th	1 / 1.2	51,218,000
Washington		Yes /	Yes	29th	2 / 7.7	26,651,000
Wisconsin	Producer credit		Yes / Yes-SA	7th	1 / 20	26,160,000
Wyoming	Producer credit			34th	1 / 5	NA

The top 5 states for corn production-Iowa, Illinois, Nebraska, Minnesota, and Indiana-are also the top ethanol producing states. All but one state (Indiana) has some form of ethanol incentive. Ethanol production is more important to these states due to the value-added market for corn and the increased profitability from ethanol production. Minnesota, for example, has a 10 year 20¢ per gallon producer payment, 15 ethanol production facilities, and the state's economy is realizing a return of $10 - $16 for every dollar of producer payment made by the state. Indiana is the only top corn producing state that doesn't offer any type of fuel incentive but still has instate production. However, they also rank 5th in ethanol production and only have one ethanol production plant (compared to the others which have at least 5). Indiana also produces less than ½ the amount of ethanol that Minnesota does (which is ranked 4th in production). These differences between ethanol production in Indiana versus the other top corn growing states may be indicative of the difference that state incentives can make.

To further support the argument that state incentives may lead to in-state ethanol production, only 3 of 12 states offering ethanol fuel incentives (Connecticut, Ohio, and Montana) don't produce ethanol. Ohio and Montana have had ethanol production facilities in the past. Although Connecticut has incentives (but no ethanol production) it also has relatively low ethanol use.

Another interesting similarity between the states shown in this table is that all but one state (Tennessee) with non-attainment areas for CO or Ozone air quality standards use ethanol, even if they are not required to do so. This may indicate that states are recognizing ethanol's ability to reduce CO and Ozone emissions. Twelve out of the fifteen states with non-attainment areas also have ethanol production. Additionally, all but two of the states that participate in the Oxy fuel program and/or RFG program (due to CO or Ozone non-attainment status) have ethanol production plants. In most cases, plants are placed in or near the areas that are required to use reformulated or oxygenated gasoline. In fact, in 7 of the 9 states, ethanol plants are in the vicinity of the areas that participate in the Oxyfuel or RFG program.

There also appears to be a relationship between state ethanol consumption and in-state ethanol production. Out of the top fifteen states with the highest ethanol use, only two (Ohio and Michigan) don't have in-state ethanol production and both of these states are currently in the planning or construction stages for ethanol production facilities. Additionally, ten of the top fifteen states for ethanol use are also in the top fifteen for the highest instate ethanol production.

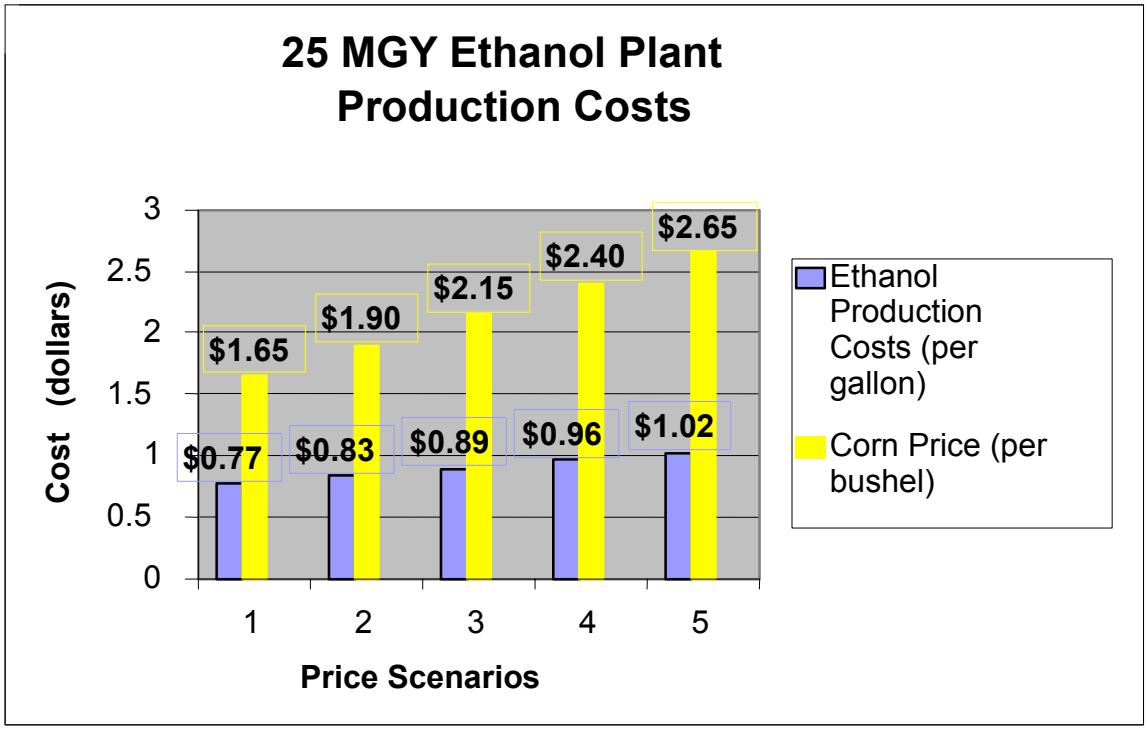
Production from Corn

Currently, the majority of ethanol is produced from corn. One bushel of corn produces about 2.7 gallons of ethanol. According to the Renewable Fuels Association, "the production of ethanol does not mean less corn available for food it…actually produces many valuable high

protein food and feed co-products." For example, "an acre of corn...produces 313 gallons of ethanol, 1,362 pounds of...protein feed for livestock, 325 pounds of 60% gluten meal, and 189 pounds of corn oil" in a wet mill process.[136] The U.S. ethanol industry consumes 560 million bushels of corn, and boosts the price of corn by 8-10¢ per bushel. When translated to income, this represents additional earnings of $2.2 billion each year to corn producers nationwide.[137]

Production Costs

The graph below demonstrates the ethanol production costs of ethanol (per gallon) at five different corn price scenarios (per bushel). The range of corn prices is based on what prices we might expect based on past price trends. The National Corn Growers Association has reported that the average U.S. corn prices in the last ten years have ranged from $1.90 to $2.71 per bushel (with the exception of 1995 when corn prices reached $3.24 per bushel).[138] Corn prices in 1995 were unusually high, mostly due to early season rains, which delayed planting and consequently lowered yields. (The USDA estimated that there was a reduction of approximately 2 million acres of corn planted in the U.S. in 1995.[139]) The rapid spread of the crop disease "gray leaf spot" throughout much of Missouri, Iowa, Illinois, and Indiana also contributed to the low yields.[140]



[136] RFA, Agriculture, Available: http://www.ethanolrfa.org/rfa2.html. 19 January 1999.

[137] RFA, Ethanol: Fueling America's…

[138] NCGA, The World of Corn 2000, p.12.

[139] Bethany Keiper, University of Mississippi State University, Corn Prices Rise as Acreage Drops, Available: http://msucares.com/new/print/cropreport/crop95/crop0623.html. 23 June1995.

[140] Paul Raeburn, The Last Harvest: The genetic gamble that threatens to destroy American agriculture, Available: http://www.nasw.org/users/praeburn/harvest.htm. 1996.

The ethanol production operating costs used in the calculations for this graph were obtained from the National Renewable Energy Laboratory report, "Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks".[141] The variables included in these costs are listed and described in the box "25 MGY Ethanol Plant Operating Costs". There would most likely be price variations in each of the listed variables for plants in different areas of the U.S. and for larger or smaller facilities. Total ethanol production costs were calculated assuming the use of .3508 bushels of corn per gallon of ethanol.

25 MGY Ethanol Plant Operating Costs

Raw materials-enzymes, yeast, and other chemicals ($0.06/gal ethanol)

Denaturant-gasoline added to the ethanol prior to shipping ($0.03/gal ethanol)

Utilities-includes price of natural gas for power and water used for cooling ($0.16/gal ethanol)

Labor, Supplies & Overhead-personnel costs, plant supplies, administration costs, insurance, and taxes ($0.13/gal ethanol)

Depreciation of Capital ($0.11/gal ethanol)

Net production costs would be lowered by the sale of dried distiller grains (DDG) and in some plants through the sale of carbon dioxide, which are co-products from the production of ethanol. Using the corn price scenarios listed above, DDG sales would decrease net production costs by $0.29-$0.40 per gallon of ethanol (assuming the yield of 6.92 pounds of DDG per gallon of ethanol).

The production cost comparisons used in the analysis are for a dry mill ethanol production facility. However, corn-to-ethanol facilities can be either wet mill or dry mill plants.

Wet mill ethanol plants

Wet mill plants tend to be larger then dry mill plants, averaging in size from 100 MGY to 300 MGY, and require a larger capital investment. Although there is a smaller number of wet mill plants, they still produce 60% of the ethanol in the U.S.[142]

In wet milling, the corn is first soaked and ground. The germ and fiber is then separated from the endosperm, and the starch in the endosperm is fermented to create ethanol. Oil is extracted from the germ, and is sold as cooking oil or used in other products such as crayons and soap. Other left over parts of the corn, such as fiber, are used for animal feed. Researchers have also been studying the advantages of using corn fiber in the fermentation process to increase ethanol yields. Using fiber could increase yields by .3 gallons per bushel of corn, translating into an additional profit of $4-$8 million dollars a year for a 100 MGY plant.[143] Some plants also capture CO_2 during the production process, selling that as well. The largest markets for CO_2 are in southern areas of California and on the East Coast. Medium markets exist in the Pacific Northwest and in some

[141] United States, NREL, Determining the Cost…, p.18.

[142] United States, National Renewable Energy Laboratory (NREL), Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks, Publication NREL/TP-580-28893, p.3.

[143] Ben Hardin, "Improving Ethanol Yield From Corn", Agricultural Research October 1996, p.8.

areas of the Midwest, such as Michigan.[144] The amount of co-products that are produced during the ethanol production process is a great advantage for wet mill plants.

Dry mill ethanol plants

Dry mill ethanol plants are typically smaller than wet mill plants (1 MGY- 60 MGY) and have lower construction, maintenance, water, and waste management costs.[145] Regardless of these benefits, dry mill plants are also more energy-intensive than wet-mill plants, and have higher total variable costs. However, total operating costs for dry mill plants do decrease as the plant size increases. In fact, the total operating costs for larger dry mill plants can be up to 22% lower than in smaller plants. By 1998, the total operating costs for dry mill plants had decreased about 16% from 1987.[146]

Dry mill plants produce ethanol by grinding the corn into a flour and then fermenting the flour. The starch in the flour is used to produce ethanol and what remains (distillers grain) is sold as animal feed. The distillers grain is normally dried and sold for about .045¢ per pound. Distillers dried grain (DDG) can increase an ethanol plant's income by 20%.[147] Additional profits are possible if feedlots are located nearby (within a 50 mile radius) because distillers grains can be sold and transported wet, thereby reducing the cost of drying the grain. Drying the distillers grain accounts for about 1/3 of the plants energy usage.[148] Wet distiller's grain (DWG) can't be transported to distant locations because it will spoil quickly when not dried. As in wet mill plants, the CO_2 created during the ethanol production process can be captured and sold if nearby markets exist. Additional co-products, which would raise the total value for dry mill plants, are currently being explored.

Production from Alternative Feedstocks

Ethanol can also be produced from feedstocks other then corn, such as rice straw, wood waste, cheese whey, bagasse (the by-product of sugar processing), and municipal solid waste. Although non-corn ethanol production is a much smaller percentage of total ethanol production, it is expanding. Some examples of this expansion include the following ethanol production facilities. High Plains Company produces approximately 70 million gallons of ethanol a year using milo and sorghum for 60% of their feedstock (with 40% corn). Georgia Pacific Paper and Ethanol Facility in Washington produce 7 million gallons of ethanol/yr. from a pulping by-product. The Simplot potato processing plant in Idaho uses by-products to produce about 4 million gallons of ethanol a year. A cellulosic ethanol plant is currently being constructed in Jennings, Louisiana and should begin operation in 2002. This plant will use bagasse to produce 20 million gallons of ethanol per year. Minnesota Brewing Co. has applied for permits to use

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144 Kathy Bryan, BBI, "Ethanol Plant Development Handbook", Michigan Ethanol Workshop Presentation, 2000.

145 Hosein Shapouri, USDA, "Overview of the First Ethanol Industry Bench Marking Survey", 2000 International Fuel Ethanol Workshop & Trade Show.

146 Shapouri.

147 United States, NREL, Determining the Cost…, p.19.

148 BBI, 2001 Ethanol Plant Development Handbook (Cotopaxi: BBI, 2001) p. 73.

brewery by-products for ethanol production at their St. Paul brewery. This could produce 15 million gallons of ethanol a year. [149]

Another cellulose-to-ethanol plant will be constructed by Masada Resources Group in Middletown, New York. This plant will process approximately 230,000 tons of solid waste and 250,000 tons of sewage sludge each year. Recyclables will be sorted out and the rest of the waste will be used to produce 9.5 MGY of ethanol. The plant will also utilize the C02 and lignin, which are by-products of ethanol production. The CO2 will be collected and sold; lignin (which contains about the same amount of energy as coal) will be gasified to produce process steam. The process, patented by Masada, to convert municipal solid waste to ethanol holds promise for increasing U.S. domestic fuel production and consuming large amounts of generated waste. This could have a considerable impact, as in 1997 alone, there were about 340 million tons of municipal solid waste generated in the United States.[150]

Another source of biomass for ethanol production is energy crops. These are fast growing crops that are raised specifically for energy use. Currently, certain trees (willow and poplar) and switchgrass are the focus of attention as energy crops because they are fast growing and require limited maintenance, fertilization, and pesticides.[151] The U.S. Department of Agriculture estimates that by 2030 approximately 129 million acres of excess cropland could be used for energy crops. If 40 million of these acres were utilized for energy crops for biofuels such as ethanol, it would provide a transportation fuel equivalent to 550 million barrels of oil per year.[152] The first energy crop-to-ethanol plant is being constructed in Canada. The plant will convert corn stover and switchgrass to ethanol. Production at this plant is scheduled to begin in 2001.

The DOE states that "biomass feedstocks represent one of the largest sustainable resources on earth" as they are produced in large quantities and can be obtained cheaply.[153] For example, approximately 240 million tons of corn stover is left over after growing corn. If 80 million tons of the left over corn stover were utilized for ethanol production (leaving the rest on the field for soil erosion control), an additional 6 billion gallons of ethanol could produced each year.[154] Feedstock costs can be up to 75% of the total cost for producing ethanol.[155] For this reason, the use of biomass feedstocks to produce ethanol is considered by many to be the key to producing much lower cost ethanol that can more readily compete with gasoline prices

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[149] BBI, The Energy Independent, Nov./Dec. 1998; BBI, The Energy Independent, January 1999.

[150] Timothy Judge, Masada Oxynol, "Orange Recycling and Ethanol Production Facility", 2000 International Fuel Ethanol Workshop, 2000.

[151] United States, DOE, "Moving Biofuels into the Mainstream: Where We Stand", DOE Strategic Plan 1996 Available: http://www.esd.ornl.gov/bfdp/doeofd/stratpla/stand.html. 28 January 1998.

[152] United States, DOE, "Moving Biofuels from Research to Market: The Major Issues", DOE Strategic Plan. 1996 Available: http://www.esd.ornl.gov/bfdp/doeofd/stratpla/issues.html. 28 January 1998.

[153] United States, NREL, Bioethanol from the Corn Industry, Publication DOE/GO-10097-577 (Golden: NREL, 1998).

[154] United States, NREL, Determining the Cost…, p.3.

[155] S. Becker, et al., Southern Illinois University, College of Agriculture, The Availability of Waste Sugar Products as an Alternative Feedstock for the Production of Ethanol, 1997.

(especially in the absence of incentives), and meet a much higher demand. Although a large increase in demand for these residues and waste feedstocks due to ethanol production will most likely increase their value, it is predicted that they still will not fluctuate or increase as much as commodity crops such as corn.[156] The cost of cellulosic ethanol production is currently estimated to be $1.15-$1.43 a gallon.[157] However, DOE estimates that energy crops "will result in ethanol costs under $1.00 per gallon by 2005 and under 70¢ per gallon by 2010." For wastes "with zero feedstock costs (e.g., municipal solid wastes)" the DOE estimates costs "to drop as low as 50¢ per gallon [by 2005] and to 34¢ per gallon by 2010."[158]

Alternative Feedstock Production Barriers

One major barrier to cellulosic ethanol production, as with most new technologies, is the large capital costs for a new plant, which are currently estimated to be $136 million for a 50 MGY plant. (Compared to corn to ethanol plants capital costs of about 28 million for a 50 MGY plant.) [159] Production costs for a cellulosic plant are also currently much higher then a corn to ethanol plant. In fact, they are almost double.[160] The problem of higher capital and production costs for cellulosic ethanol production is exacerbated by the difficulty in obtaining financing for a new and, therefore, riskier technology.[161]

One reason production costs are so much higher is the expense of enzymes used in cellulosic ethanol production. Research is currently being conducted on producing these enzymes in a more efficient and cost-effective manner.

Another downside to cellulosic ethanol production is the intensive pre-treatment process that is required to unable the biomass to be fermented to produce ethanol. Much of the research and development of cellulosic ethanol production is focusing on using a combination of both physical pretreatment methods and chemical pretreatment methods (using acid, ammonia or other chemicals).[162] These intensive pre-treatments add cost and time to the ethanol production process.

Ethanol Production in Michigan

By 1983, two ethanol plants had been established in Michigan--a 1.5 MGY plant in Litchfield, and .3 MGY plant in Bronson. Construction was planned for a third plant in Alma (8 MGY), but it was never completed. All the facilities were corn dry mill plants. The Alma plant was financed by a group of farmers and an U.S. Economic Development Administration loan

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156 United States, NREL, Determining the Cost…, p.2.

157 Joseph DiPardo, EIA, Outlook for Biomass Ethanol Production and Demand, 2000.

158 United States, DOE, "Moving Biofuels into the Mainstream…", p.3.

159 United States, NREL, Determining the Cost…, p.19 & 22.

160 Production costs for a 50 MGY corn to ethanol plant is approximately 22 million and for a 50 MGY cellulosic plant production costs are about 37 million. United States, NREL, Determining the Cost…, p.18 & 20.

161 Angela Graf and Tom Koehler, Oregon Cellulose-Ethanol Study, Report Prepared for the Oregon Office of Energy, June 2000, pp.21-22.

162 Graf, p.57.

guarantee, but costs exceeded budget and the plant was never completed. The Litchfield plant was closed after approximately 16 months of operation due to poor plant design and financial problems. The operation at Bronson was relatively small and therefore operating costs were much higher than revenues. It was closed in 1986.[163]

Interest in establishing new ethanol production facilities in Michigan has recently resurfaced in response to extraordinary low corn prices. Corn is the leading crop in Michigan (acreage planted and value). Approximately 2/3rd of Michigan's corn is exported out of state.[164] The economic impact of ethanol production in Michigan is such that a 15 MGY plant would utilize approximately 6 million bushels of corn each year, adding approximately $1.70 in value to each bushel of corn. This would almost double the value of corn from current selling prices.[165]

Construction has recently begun on Michigan's first large-scale ethanol production plant. The 40 MGY plant is scheduled to be completed by the fall of 2002. When the ethanol plant is successfully established, it is estimated that "more than $88 million [dollars] will be added to the Michigan economy each year."[166]

Ethanol Production Summary

Current challenges for the ethanol industry include: continuing to increase production efficiency and yields, and to increase production form readily available/low-cost biomass feedstocks. Ethanol production has had several economic impacts, including creating new jobs and generating additional local and state revenues.[167] As alternative feedstocks, such as biomass and energy crops, become increasingly utilized for ethanol production, the cost of producing ethanol will continue to decrease. This will enable ethanol to compete with gasoline prices and, at the same time, meet higher demand.

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[163] State of Michigan, Department of Agriculture, Alcohol Fuels..., pp.5-6.

[164] Dale Sherwin, Michigan Department of Agriculture, Director of Agriculture Policy, Personal communication, 1999.

[165] John Ferris, Michigan State University, Evaluation of the Economic Impact of a Dry Mill Ethanol Plant in Michigan Using Corn as a Feedstock, p.7.

[166] CMP, Ethanol…

[167] Evans.

Chapter 5
Environmental Impacts of Ethanol Versus Gasoline

Ethanol generally burns cleaner than petroleum fuel because it is made-up of organic compounds, which are less complex chemically than gasoline and diesel fuels. Because they are less complex and burn more completely, they do not leave as many residues that cause polluting emissions. The Renewable Fuels Association recently wrote that ethanol "is one of the best tools we have to fight urban air pollution" because it burns much cleaner then gasoline and reduces most exhaust emissions.[168]

National Ambient Air Quality Standards

The Clean Air Act and Amendments require the EPA to monitor U.S. air quality and establish National Ambient Air Quality Standards (NAAQS). If an area of the country exceeds those standards for any of six "criteria pollutants," it is designated as being in non-attainment for that pollutant. The six criteria pollutants are carbon monoxide, ozone, particulate matter, nitrogen oxides, lead, and sulfur dioxide. Non-attainment is broken down into five categories—marginal, moderate, serious, severe, and extreme. Some of the criteria pollutants have been linked to minor health problems, such as coughing and shortness of breath, and to more serious health problems, including death.

Health care costs linked to air pollution were estimated by the American Lung Association to be 50 billion dollars each year.[169] The use of ethanol to reduce the five transportation-related pollutants—carbon monoxide, ozone, particulate matter, nitrogen oxides, and lead—is addressed in this chapter. Carbon dioxide and aldehyde emissions are also discussed. Emissions produced during the ethanol or gasoline production processes (growing the crops, transportation of the fuel, etc.) are not discussed.

Carbon Monoxide (CO)

Carbon monoxide is a poisonous gas and the leading source of air pollution in the United States. High levels of CO can cause nausea, headaches, and other serious health problems. The Department of Energy has stated that 82% of CO emissions are due to transportation.[170] The Clean Air Act Amendments of 1990 mandate the use of oxygenated gasoline in areas that do not meet carbon monoxide attainment standards during winter months. This is when CO emissions are highest. As a result, 39 areas are required to use oxygenated fuels. Ethanol is the most commonly used fuel additive for oxygenated fuels. EPA found that carbon monoxide violations were reduced by 90% during the first year of the Oxygenated Fuel program.[171]

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[168] RFA, Ethanol: Fueling America's…
[169] CFDC, 1999 Fuel Ethanol…, p.10.
[170] CFDC, 1999 Fuel Ethanol…, p.10.
[171] CFDC, 1999 Fuel Ethanol…, p.16.

Tests by the University of Colorado showed CO emission reductions in automobiles of up to 30% when 10% ethanol blends were used.[172] The use of 10% ethanol blends has also been shown to reduce CO emissions when used in snowmobiles. These reductions are particularly important for snowmobiles as they emit almost 40 times more carbon monoxide then a car.[173] Because of snowmobiles high emissions, there is a debate about whether or not they should be restricted or banned in U.S. national parks. Yellowstone Park staff members have begun using ethanol-blended fuels in their snowmobiles and park vehicles to reduce emission health and environmental impacts.

CO emission reductions may also be achieved through the use of oxygenated diesel fuel. Oxygenated diesel, which consists of ethanol blends of 7.7-15%, is currently being tested in buses and heavy-duty trucks. Initial emission testing showed CO reductions of approximately 27% when using 15% ethanol blends. Twenty-percent reductions were experienced with 10% ethanol blends. An additional benefit of using 7-15% ethanol blends in diesel is that no engine modifications are required.

Ozone

Ground-level ozone is the main cause of smog. It can result in eye irritation, coughing, and shortness of breath. The EPA reports that exposure to ozone "has been linked to increased hospital admissions for respiratory aliments, such as asthma" and that "repeated exposure…can make people more susceptible to respiratory infection and lung inflammation."[174] It can also cause significant damage to plants, reducing crop yields.[175]

Over 30% of ozone emissions can be attributed to motor vehicles.[176] To decrease emissions the Clean Air Act Amendments of 1990 mandated the use of reformulated fuels in the most serious ozone non-attainment areas. The 1-hour ozone standard, set in 1979, stipulated that areas could not exceed ozone concentrations of .12 parts per million (ppm), more than once per year, when averaged over a 3-year period. In 1997, the EPA established a new 8-hour ozone standard. For this standard, EPA stipulates that "an area will attain the standard when the 3-year average of the annual 4th-highest daily maximum 8-hour concentrations is less than or equal to .08 ppm."[177] Currently, EPA classifies 14 counties in Michigan as non-attainment areas for the new "8 hour" ozone standard.[178] When a state has an area in non-attainment they must submit a

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[172] United States, NREL, "Ethanol: Separating Fact from Fiction", Biofuels: Ethanol for Sustainable Transportation Factsheet, Prepared for DOE, Publication DOE/GO-10099-736, April 1999, p.2.

[173] Donald Barry, Assistant Secretary, U.S. Department of the Interior, Congressional Testimony, May 25, 2000, Available: http://www.nps/gov/legal/testimony/106th/snowmobl.htm 13 April 2001.

[174] United States, Environmental Protection Agency (EPA), Fact Sheet: "EPA's Revised Ozone Standard", July 17, 1997, Available: www.epa.gov/ttn/oarpg/naaqsfin/o3fact.html 27 March 2001.

[175] CMP, Use Ethanol Blended Gasoline Today...Breathe Easier Tomorrow, (Lansing: CMP, 1997); Green Fuels, Environmental Effects of Ethanol and Gasoline, Available: http://www.greenfuels.org/ethaenv1.html, 1998.

[176] CFDC, pp.5-6.

[177] United States, EPA, "EPA's Revised Ozone Standard".

[178] United States, EPA, Areas Violating the 8-Hour Ozone Standard, Available: http://www.epa.gov/ARD-R5/naaqs/8o3_nmap.htm 1 April 2001.

State Implementation Plan (SIP), which describes how they plan to reduce pollution and meet attainment standards.

The EPA has reported significant reductions in ozone-forming emissions due to RFG. The RFA equated these reductions to "taking 16 million vehicles off the road each year."[179] Although ethanol can be used for reformulated gasoline to achieve the required reduction in ozone-forming emissions, MTBE has been most often used as the additive for RFG. As previously discussed, the use of MTBE is currently being curtailed due to water contamination issues, and many states have even banned its use. It is therefore expected that ethanol will now be used in areas mandated for RFG.

Particulate Matter

Particulate matter is a result of the incomplete combustion of fuel. It can affect breathing, exasperate existing respiratory and cardiovascular problems, and cause other serious health problems. By using even small amounts of ethanol-blended fuel, such as in RFG, particulate matter can be reduced by almost 10%.[180]

Nitrogen Oxides

Nitrogen oxides contribute to ground-level ozone, global warming, and acid rain. The U.S. DOE reports that, "acid rain causes an estimated $2 to $3 billion in damage to agricultural crops in the United States each year."[181] Approximately 57% of Nitrogen Oxides emissions in U.S. cities are from transportation vehicles.[182] The use of E-85 reduces vehicle nitrogen oxide emissions by 10%.[183]

Lead

The 1978 Clean Air Act Amendment resulted in the EPA adding lead to its list of criteria pollutants. The imposition of standards has resulted in eliminating lead as an additive for octane enhancement in gasoline. This has opened up the market to new octane-enhancement products, including ethanol. The National Corn Growers Association estimated in 1990 that "ethanol displaces the octane equivalent of 4 billion grams of harmful lead components in gasoline."[184]

The aviation sector was given a "temporary" waiver for the elimination of lead in aviation fuel. Today, more than 20 years later, many are calling for the industry to finally remove lead from aviation fuel. One unleaded aviation fuel alternative is AGE-85, which contains 85% ethanol. AGE-85 has been certified for use in several models of piston-engine aircraft.

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[179] Vaughn, p.2.

[180] CFDC, 1999 Fuel Ethanol…, p.17.

[181] United States, EIA, Factsheet: "Biofuels…Better for the Environment".

[182] CFDC, 1999 Fuel Ethanol…, p.10.

[183] State of Michigan, Alternative Fueled Vehicle Inter-Departmental Task Force, Michigan State Plan for Alternative Fueled Vehicles (Lansing, 1996), p.14.

[184] NCGA, Ethanol: A Clean Breeze…

Carbon Dioxide (CO_2)

Carbon dioxide is a byproduct of burning fuels. It is not toxic, but it does contribute to global warming. The EPA has stated that the U.S. is responsible for about one-fifth of the worldwide greenhouse gas emissions that cause global warming.[185] The Department of Energy's Los Alamos Laboratory has reported that "carbon dioxide in the atmosphere has risen from about 280 parts per million…to the current level of over 360 parts per million" and "is expected to rise to approximately 600 parts per million…during the next century."[186]

These CO_2 increases, coupled with other greenhouse gases, may increase the average global temperature by up to 3.5°C.[187] Although, at first glance, this appears to be a minimal temperature change, it can produce negative climatic impacts, such as extreme weather changes and significantly increasing sea levels.

Motor vehicles account for 30% of CO_2 emissions.[188] The use of ethanol in vehicles results in the release of CO_2, but the plants grown to produce ethanol absorb at least as much carbon dioxide as is released during ethanol production and use. The Corn Marketing Program of Michigan states that, "the amount of CO_2 released by burning one gallon of ethanol is equal to the amount of CO_2 absorbed by the corn grown to make one gallon of ethanol."[189] Consequently, the net amount of carbon dioxide does not increase as it does through fossil fuel use.

Environmental Barriers

Ethanol is not always recognized for its environmental benefits. This may be related to the relatively limited amount of research that has been conducted in this area, especially with respect to potential emission-reduction capacity. Also, the studies that are available often vary in regards to emission reduction amounts. There additionally appears to be a lack of consensus on how such research should be conducted. For example, some emission-reduction research focuses on vehicle emissions only. Other research is broader in scope, studying the ethanol production process and vehicle emissions.

Another barrier is that no monetary value is placed on ethanol's environmental benefits. The issue of assigning monetary value for environmental benefits is a chronic debate associated with the development of renewable energy sources. These technologies and fuels are often not competitive price wise with established and commonly used fossil fuels. Attaching a monetary value in the form of imposing a tax or adding costs would "level the playing field" for renewable

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185 United States, EPA, Global Warming: Climate, Available: http://www.epa.gov/globalwarming/climate/index.html 13 April 2001.

186 United States, DOE, Los Alamos National Laboratory, p.29.

187 United States, DOE, Los Alamos National Laboratory, p.30.

188 State of Michigan, Alt. Fuel Task Force, p.13.

189 CMP, Use Ethanol Blended Gasoline…

fuels. The tax or added costs could then be used to clean up oil spills, manage mining wastes, and remedy other environmental damage from fossil fuels.

Another way to create economic value for environmental benefits would be to assess a tax on higher polluting vehicles or offer tax rebates to drivers who operate less-polluting vehicles. With alternative-fueled vehicles, drivers would have to prove that they are refueling with an alternative fuel, as most are flexible fueled vehicles, which can operate on 100% gasoline.

There are some additional environmental barriers for the use of ethanol with respect to aldehyde emissions and volatility.

Aldehydes

Oxygenated gasoline (including that made with ethanol) has higher aldehyde emissions than regular unleaded gasoline. The primary component of aldehyde emissions from ethanol is acetaldehyde, which is toxic and possibly a carcinogen. However, with improved exhaust systems, vehicles manufactured after 1987 reduce the emissions to approximately that of gasoline. "The Royal Society of Canada termed the possibility of negative health effects [from the emissions] ... as being remote."[190]

Volatility

Another potential problem with the use of ethanol blends in gasoline is that it raises evaporative volatile organic compounds (VOCs). A 10% ethanol blend raises the Reid Vapor Pressure (Rvp) by 1 pound. By themselves, VOCs are not a problem. However, when combined with CO and other chemicals they can create ozone. Although lower volatility gasoline can be produced to offset this VOC increase, petroleum companies have argued that it will cost much more to produce. (It is predicted to raise the cost by 1-2¢.) [191]

The Institute for Local Self Reliance has reported that petroleum companies "are reluctant to produce low volatility gasoline, especially if they only need to produce it for a few areas." The Institute also concluded that, although ethanol may increase evaporative VOCs, they "decrease…exhaust pipe VOCs, which are more reactive and more toxic." The study also found that reductions in CO emissions from ethanol blends offset any increases in VOC emissions. [192] The EPA recently announced that they will take these CO reduction benefits into consideration by allowing "additional flexibility in meeting the…VOC standard in RFG used in Chicago and Milwaukee that is blended with 10% ethanol."[193]

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[190] GreenFuels, How Does Ethanol "Clear the Air"? Available: http://www.greenfuels.org/ethaair.html, 1998.

[191] David Morris, "Carbohydrates Could Solve the California Water Crisis", The Carbohydrate Economy, Spring 1999.

[192] David Morris and Jack Brondum, Institute for Local Self-Reliance, The Other Gasoline Crisis: Speeding Up the Shift From MTBE to Ethanol, September 2000, Available: http://www.ilsr.org/volatility.html 2 October 2000.

[193] RFA, "EPA Announces VOC Adjustment in Recognition of Ethanol's Carbon Monoxide Reduction Benefits", Ethanol Report, March 26, 2001.

Environmental Impact Summary

Using ethanol-blended fuel can reduce carbon dioxide emissions and addresses five of the six pollutants monitored by the EPA. These pollutants contribute to smog, acid rain, global warming, and health problems. However, the environmental benefits of ethanol will not be understood unless more extensive research is conducted. Policies that place monetary value on its use (associated with the environmental benefits that it produces) may also be needed to stimulate the adoption of alternative fuels, such as ethanol.

Chapter 6
Conclusions, Assessments, and Recommendations for Further Research

Bolstering ethanol production and use will reap benefits such as: increasing U.S. and state income and employment, decreasing dependency on foreign oil, retaining more dollars in local economies, increasing corn producers' profits, and reducing most vehicle emissions. The value-added to corn due to ethanol production is especially important in Michigan because corn is the state's leading crop as measured by acreage planted and in economic value.[194]

Although ethanol production and use has experienced a resurgence recently, it is unclear whether this prominence will continue or abate as it has in the past.

Issues Associated with Ethanol Development

Ethanol production and use will be negatively affected if Federal incentives, which are set to expire in 2007, are not extended. These incentives enable ethanol to compete with gasoline, especially when 10% or lower blends are used. The largest profits are obtained when ethanol is blended with cheaper, sub-octane gasoline. Ethanol's high octane rating boosts the sub-octane gasoline to required octane levels, and
does so less expensively than when using only gasoline and/or gasoline additives. In the absence of incentives, ethanol production costs are currently too high for ethanol to compete directly with gasoline unless gasoline prices continue to dramatically rise. Reported ethanol production costs vary from 88¢ to $1.25 per gallon. The wholesale price of gasoline in 1999 was around 60¢ per gallon. [195]

Ethanol use and production could also be negatively impacted by corn price increases, such as those that occurred at the end of 1995. The 1995 corn price increases represent a major reason why ethanol production, which had risen steadily from the late 1980s, experienced a sharp decline.

Even if the ethanol industry successfully conquers these barriers, there are still additional issues that have to be faced. One issue pertains to ethanol's viability vis-à-vis the development of alternative technologies, such as electric, hybrid or fuel cell vehicles. When compared to E-85 powered vehicles, all of these technologies possess superior emission reduction capabilities and are more fuel-efficient. However, these technologies do not come without challenges. For example, emissions are created when electricity to recharge electric vehicles is produced. Also, with fuel cell vehicles, it is expected to be quite some time before on-board hydrogen technology

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[194] State of Michigan, Department of Agriculture, 1997-98 Michigan Agricultural Statistics, Available: http://www.mda.state.mi.us/mass/stats98/crops.htm, 19 January1999.
[195] CFDC, 1999 Fuel Ethanol…, p.26; United States, NREL, Determining the Cost…, p.4.

is perfected. When on-board hydrogen is available the hydrogen infrastructure will still need to be developed.

Even if these technologies are developed over the long term, at the very least ethanol could be an interim solution—filling in the gap and used for fuel cell vehicles until the hydrogen market and technology are developed. But therein lies a dilemma: Some view ethanol as a "transition fuel" with limited longer-term potential and usage.

Another criticism facing the ethanol industry is the potential decrease in Federal Highway Funding to states due to the ethanol tax credit. The Michigan Department of Transportation reports that the use of gasohol in Michigan resulted in a loss of approximately "$23 million per year for the period 1998-2001" in highway funding, and losses are predicted to reach "$55 million in 2002."[196] Other states are claiming similar, or even larger, losses of highway funds due to ethanol. For example, the Ohio Department of Transportation reports that the state will lose approximately $180 million in federal highway funds per year.[197] Both Ohio and Michigan are "donor states," meaning that federal highway funds are based on what the state pays into the Highway Trust fund from fuel taxes. When ethanol is used, less is contributed to the Highway Trust fund. Why? There is a 5.4¢ tax reduction for ethanol and 2.5¢ of the federal fuel tax collected for ethanol is appropriated to the Federal General Fund. Therefore, the use of ethanol in donor states reduces their contribution to the Highway Trust Fund, and thereby reduces the amount of Federal highway funds allocated to the state. To remedy this, Ohio is proposing that: 1) all of the fuel tax on ethanol go to the Highway Trust Fund instead of having a portion go to the General Fund; and 2) Federal highway appropriations not be reduced when ethanol is used.[198]

Regardless of the issues that the ethanol industry has to address, several things are certain: ethanol production is a value-added product for farmers, and ethanol is beneficial as a waste reduction solution.

Ethanol Development at the State Level

It appears that states with strong leadership and organizational involvement, such as Minnesota and Illinois, have been more successful in ethanol-related development (i.e., building ethanol plants, creating incentive programs, etc.). What is not clear is whether congressional and legislative support in these states is an inherent outgrowth of their status as top corn-producing states or if strong leadership and active ethanol-related organizations create congressional and legislative support.

In the past, limited leadership and presence of ethanol advocacy groups in Michigan has hindered the state's ethanol development. Until 1999, when a DOE-sponsored ethanol workshop was held in Michigan, ethanol interests were fragmented and generally disconnected. Before the

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[196] Aarne Frobom, Michigan Department of Transportation, "Reductions in Federal Aid to Michigan Attributable to Gasohol Sales", Presentation to Ethanol Working Group, 2001.
[197] Ohio Department of Transportation, Ethanol Funding Issues, February 23, 2001.
[198] Ohio Department of Transportation.

workshop staff members at the State Biomass Energy Program, including this researcher, were unaware of many individuals and organizations working on ethanol-related issues. But after a second ethanol workshop was held in 2000, an Ethanol Working Group (EWG) was formed. The EWG is a coalition of representatives from various organizations, universities, and state agencies concerned with promoting ethanol in Michigan. This group is focusing on educational efforts for students, agricultural producers, and owners of flexible fuel and off-road vehicles. The EWG also plans to partner on future projects with groups not currently represented in the group.

Forming partnerships, such as the EWG, has significantly enhanced the ethanol potential in Michigan. Michigan now has eight E-85 refueling sites with ten more in the planning stage (there were only two sites as late as 1998). There will also be in-state ethanol production in the near future.

Research Recommendations

Research on State Incentives

Further research needs to be conducted on the impact of state incentives on in-state ethanol use and production. Although it appears that incentives do have an impact on in-state ethanol production, further analysis is warranted, especially on the extent of the impacts. Even though Michigan doesn't offer any direct ethanol incentives, designating an area as an "Agriculture Processing Zone" will exempt production facilities in that area from virtually all state and local taxes for 15 years. These state and local tax exemptions are thought to equal many other states ethanol incentives. The impacts of Agriculture Processing Zones need to be studied and better understood.

Research on Environmental Impacts

There also appears to be a need for further research on the environmental impacts associated with using ethanol versus gasoline, as well as how ethanol compares with other alternative fuels such as natural gas, propane, and methanol. Studies need to focus attention on potential vehicle emission reductions as well as the emissions produced during the production process. It will be helpful to have a breakdown of the components/additives included in gasoline when conducting fuel comparisons. One reason for doing this: although ethanol may have negative environmental impacts, such as increasing VOC's and/or volatility, those impacts may be insignificant when compared to gasoline and its potentially harmful and toxic additives, such as benzene, n-hexane, and toluene.

Research on Economic Impacts

Further research on the economic impact of ethanol may also be warranted. Dr. Michael Evans completed an economic study of ethanol, touted as "the first comprehensive analysis of the macroeconomic impacts of ethanol production," in 1997.[199] This report is frequently cited in reports, studies, and articles on ethanol. A revised, comprehensive economic study is necessary because the ethanol industry has changed significantly since 1997. Additionally, the Evans study

[199] Evans.

focused on corn ethanol and did not include an analysis of the emerging biomass ethanol industry.

Tracking Ethanol Use and Price

There is also a lack of comprehensive tracking of ethanol use and price. The only up-to-date tracking is done by the Federal Highway Administration (FHA), and is based on Federal tax revenue. A FHA representative told me privately that these data are based on "loose estimates" and are not necessarily the best source to track ethanol consumption. The FHA source also believes that some states provide more reliable data then others. Even at its most reliable, these data do not include ethanol used in E-85 blends. It only references ethanol used in gasohol, and in oxygenated and reformulated gasoline.

For many states, the use of E-85 is currently small. Yet to adequately track E-85 use and predict future growth, procedures should be in place to report E-85 use. The data that are currently collected on state gasohol use are based on different sources, and the collection methods vary. For example, the FHA states that Michigan gasohol consumption (including the gasoline portion) for 1999 was nearly 359 million gallons.[200] The Michigan Department of Transportation reports use at about 327.7 million gallons.[201] For many states the difference in state and federal ethanol consumption data is even more extreme.

It is even more difficult to find comprehensive data on the price of ethanol (both production and retail price). There is only one source known to this researcher that track price on a daily and monthly basis, *Oxy Fuel News*. But this is a subscription-based publication at nearly $1300 per annum. Limited access to data on the price and use of ethanol makes it extremely difficult to monitor price and use patterns, and to predict future use and price possibilities. It also limits research on variables that may impact use and price.

Research on International Ethanol Use and Production

International use and production of ethanol should also be studied further. This researcher discovered some information on the use and production of ethanol in Brazil, and on the possibility of an ethanol plant being built in China, but didn't explore the international experience with ethanol further. It is important to explore international experiences with ethanol if we are to fully understand its limits and potential.

Research on Perceptions about Ethanol

It would also be useful to study individual perceptions of ethanol and whether stereotypes of gasohol from the early 1980s persist (e.g., using gasohol can damage your engine). This perception was formed because of problems associated with improperly blended gasohol. However, since the 1980s, blending requirements have been enacted making it virtually impossible for problems to occur. It also appears that many confuse ethanol, which is a renewable and harmless alcohol, with methanol—a highly corrosive and toxic fuel that is

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[200] United States, Department of Transportation.

[201] Frobom.

produced from petroleum products. This confusion stems from both fuels being labeled "gasohol" in the early 1980s.

There has also been the perception that more energy is used to produce ethanol then the energy output when it is used as a transportation fuel. (That there is a negative energy balance.) There was some information/reports circulated in the 1980s and 90s, to this effect. This information has been invalidated by more recent analyses. Yet, when this researcher makes presentations on ethanol, audience members still frequently raise this issue.

Exploring any perception differences between state and/or regions in the U.S. would also be beneficial to determine perception barriers that may need to be overcome to increase ethanol acceptance and use.

Strengths and Limitations of this Study

The original research for this study was conducted under the auspices of a unit of Michigan State government. That affiliation made it possible for the researcher to have access to many experts and resources that may have otherwise remained untapped. Another strength of this study is its comprehensiveness. Most ethanol reports focus on a particular aspect, such as a particular ethanol market or ethanol production process.

On the other hand, there are topics that could have been explored in a more in-depth manner, such as the economic impact of ethanol (including biomass ethanol), the environmental benefits of ethanol versus gasoline, and the impact of state ethanol incentives on instate use and production. There were also areas that would have been more difficult to research, but could have been included, such as the factors that promote and inhibit in-state use and production of ethanol, and international experiences with ethanol.

Closing Statement

In comparison to other alternative fuels, ethanol may not provide the largest reduction in emissions or the best mileage. But it is renewable, produced domestically, and provides economic benefits to farmers. Although there are many questions still unanswered regarding ethanol's future, studies like the one undertaken here will hopefully guide us in a constructive direction.

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